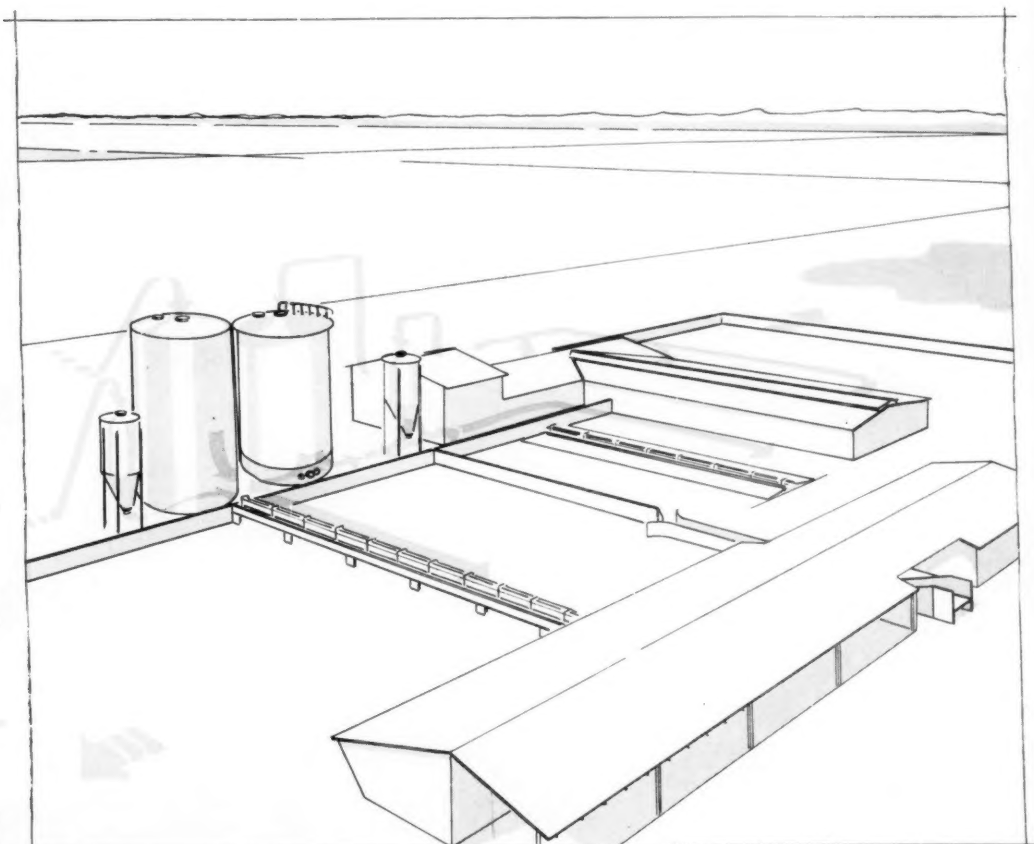
SEPTEMBER 1960

Agricultural Engineering

The Journal of the American Society of Agricultural Engineers

FARMSTEAD ENGINEERING CONFERENCE ISSUE

Confinement Housing of Livestock



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Agricultural Engineering

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CONTENTS · SEPTEMBER, 1960 · Vol. 41, No. 9

SUBSCRIPTION PRICE: $8.00 a year, plus an extra postage charge to all countries to which the second-class postage rate does not apply; to ASAE members anywhere, $4.00 a year. Single copies (current), 80¢ each. This special September Farmstead Engineering issue $1.25 each (10 or more copies, $1.00 each).

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About the Cover

AGAIN as in 1958, when a special cover was required for the Materials Handling Conference issue, we called upon ASAE member Phil F. Wendell, one of the pioneers in the development of "system farming," to design a special cover for this issue. Again the assignment was the same—to illustrate a schematic operation confined to the subject at hand, yet one that would require some imagination and forethought to consider it as a workable plan.

In Phil's own words, "In case anyone wants to know about the drawing, it represents a hog and beef operation. I won't tell you any more about it since it's more fun to beat it around trying to figure out what the man had in mind for gosh sakes. I will comment, though, that this drawing would be practically number 3 of 4 for an application engineer on a supply house payroll. The first drawing would be a top plan layout; the second would be a trial perspective (find wad in corner near wastebasket); then this. The final drawing would be for actual equipment with consolidation of flow lines. And, if a standards committee will get busy, maybe we will later be able to shorthand these flow circuits like radio or plumbing circuits with symbols for process stages and other equipment."

Although Phil's design covers a hog and beef operation it should be, as Phil says, "more fun to beat it around trying to figure out" a workable plan for poultry, swine, dairy, beef or combinations thereof.

ASAE Motion Picture

Because of a space shortage in this issue a report on the ASAE motion picture, "Agricultural Engineering—Profession with a Future" will not be carried. However, a complete report will be carried in the October issue. In the meantime ASAE members are urged to check with section leaders or department heads in order to make full use of this new tool in promoting our profession.

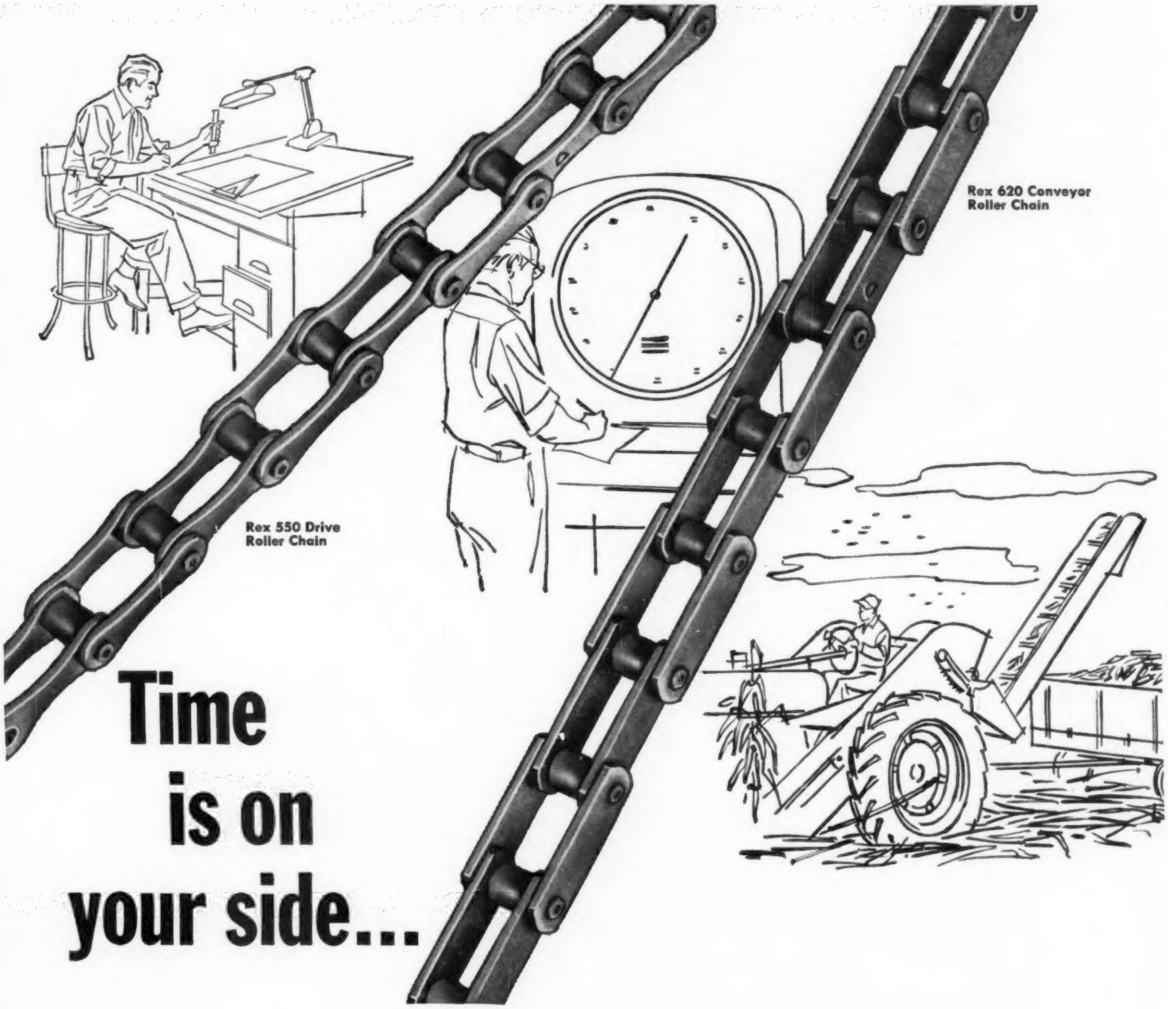
Building Research Institute Plans Conference

The Building Research Institute will stage its 1960 Fall Conferences at the Shoreham Hotel, Washington, D. C., November 15-17. The three-day session will include conferences on "Preassembled Components," "Structural Foams," "Fasteners and Anchorage Devices for Industrial Curtain Walls" and "Building Research." Further details may be obtained by writing to BRI, National Academy of Sciences, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

AGRICULTURAL ENGINEERING is owned and published monthly by the American Society of Agricultural Engineers. Editorial, subscription and advertising departments are at the central office of the Society, 420 Main St., St. Joseph, Mich. (Telephone: YUkon 3-2700).

JAMES BASSELMAN, *Editor and Publisher*

Note: AGRICULTURAL ENGINEERING is regularly indexed by Engineering Index and by Agricultural Index. Volumes of AGRICULTURAL ENGINEERING, in microfilm, are available (beginning with Vol. 32, 1951), and inquiries concerning purchase should be directed to University Microfilms, 313 North First Street, Ann Arbor, Michigan.



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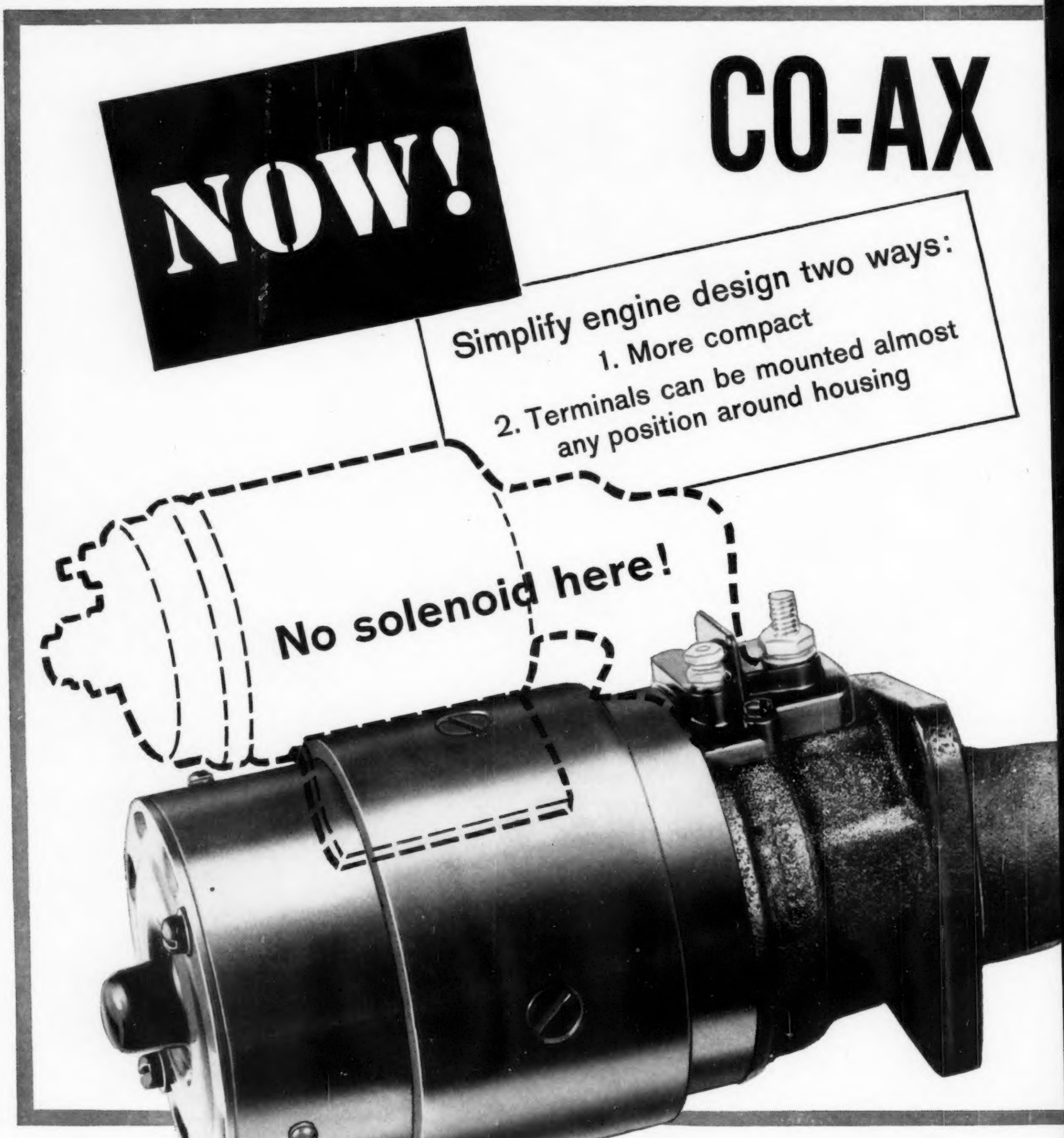
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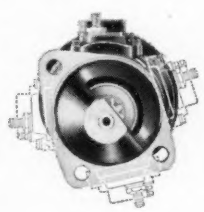

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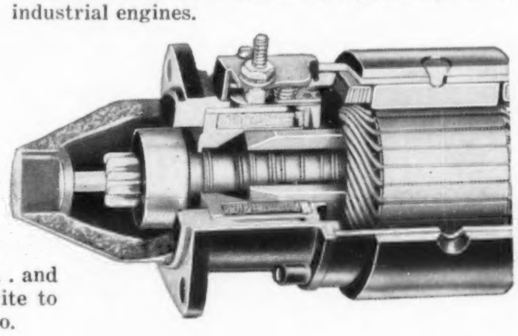

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Report to Readers . . .

ENGINEERS DEVELOP AXIALLY FLEXIBLE AUGER CONVEYOR Cornell agricultural engineers report completion of a successful working model of a flexible auger conveyor. This model, one of a number of designs being considered, was tested for conveying wheat at various angles and varying degrees of curvature. The model handled material at near the capacity of a standard auger conveyor, with a slight decrease in conveying efficiency, which became greater as the curvature of the conveyor increased. No wear on the interior of the flexible tube was noticeable after the conveyor had been used to convey wheat for several days. . . . In one test the intake was held horizontal while the remaining length of the auger was used for shifting to a steep elevating angle. It was apparent from this test that the capacity of the conveyor is governed by the angle of the intake. Near horizontal capacity was obtained even though most of the conveyor was at an angle considerably above the horizontal. This result led the engineers to the conclusion that one practical use of the flexible auger might be for transition from horizontal to vertical elevation which could provide near horizontal capacity for a vertical elevator. . . . Further work on the conveyor is to be directed toward developing a more economical and simple design.

SEPTIC TANK EFFLUENT DISPOSAL THROUGH TOP SIDE OF DRAIN PIPE Michigan SU agricultural engineers report their observations of an experimental septic-tank drain made of 4-inch asbestos-cement pipe and laid so as to leave slots in the top side of the drain 1/4 inch wide and 1 inch deep. Watertight couplings were used to keep the effluent standing in the lower three-fourths portion of the drain, to permit the suspended solids to settle out in the drain pipe, instead of clogging the soil surrounding the drain. This arrangement provided approximately 10 cubic feet of storage space for the solids within the drain pipes. A silt well at the end of each branch of the drain supplied additional sludge storage, also a means for removing the sludge from the drains. . . . . After three years of service, liquid levels within the drains and silt wells were normal, and there was only a small amount of black sludge in the silt wells.

ALL-WEATHER PLASTIC FILMS SHOW PROMISE FOR FARM-BUILDING USE A USDA-Kansas SU research team reports that it sees no reason why the new all-weather products, such as weatherable polyester, cellulose acetate-butyrate, and polyvinyl fluoride should not have a real future for semi-permanent and permanent farm buildings. . . . After four years of work with these plastics, the USDA agricultural engineer on the research team makes these suggestions: All-weather plastic films of at least 3 mil thickness (preferably heavier) should be used for outdoor construction, either semipermanent or permanent. Reasonably good construction practices in the use of plastic films are essential. It is further recommended that the intervals between framing members, to which films are attached, should not exceed 20 to 24 inches. Also, the films should be cemented to the frames or fastened with a heavy-duty stapler every 2 inches and then covered with lath or lattice stock nailed every 6 to 8 inches. The researchers were supplied recently, for testing purposes, with samples of a clear plastic film that is crisscrossed with strings of fiberglass, which the manufacturer predicts will be much stronger and have greater dimensional stability. . . . The engineer associated with these studies is of the opinion also that, with reasonably good construction practices, all-weather plastic films will retain heat about as well as glass, especially if a double layer of film with a dead air space between is used. Besides reducing heat loss, which it is estimated can be cut as much as 40 percent, the double layer of film will also reduce moisture condensation.

(Continued on page 544)

EQUIPMENT FOR STORING AND REMOVING SILAGE DUE FOR FURTHER IMPROVEMENT

Now that the use of tower silos and mechanical unloaders and feeders is rapidly increasing on cattle-feeding farms, more intensive study devoted to removing the bugs in such equipment is urgently needed. This opinion was advanced this summer by a Minnesota agricultural engineer at an ASAE meeting. This engineer recommends that such equipment be designed to handle both hay and silage, so the production of either may be carried on with a minimum of change-over or adjustment of equipment in accordance with weather conditions or crop requirements. There is need also to design unloading equipment and bunk feeders that require less power; the fact is power suppliers are said to be concerned because some installations require motors with a capacity up to 18 hp that may operate only 35 to 40 minutes a day. . . . For filling silos, suitable devices are needed for proper distribution of silage to produce uniform chemical and bacteriological action and to equalize stresses on the silo. More attention should be given also to bottom unloading of and to self-feeding equipment for tower silos. This type of silo is also much in need of a simple, safe, dependable man lift.

ENGINEERS REPORT ON STUDY OF HYDRAULIC REMOVAL OF MANURE

Michigan SU agricultural engineers have reported results of their investigation of manure removal by hydraulic means. Equipment used in the study was designed and built to determine the effects of nozzle shape, water pressure, and roughness of surface on cleaning manure from concrete. (For the purpose of this study, it was determined that fine sand could be used in place of actual manure for quantitative measurement of manure removal.). . . . A highly significant improvement in cleaning effectiveness resulted when pressures, using a solid-spray nozzle, were increased from 60 to 80 psi. Improvement at 100 psi was still significant over 80 psi, but at 120 psi pressure it was not significantly better than at 100 psi. The solid-jet nozzle proved to be best for the purpose. . . . The effect of roughness of the concrete surface on cleaning effectiveness was found to be negligible.

ENGINEERS DESIGN COMPLETE SYSTEM FOR AUTOMATIC FEEDING OF POULTRY

A USDA-Illinois AES agricultural-engineering research team has had under study the automatic feeding of poultry on a commercial farm producing turkeys and roasting chickens in the tens of thousands each year. Their objective was to develop a method of conveying the feed to the feeding points, as well as the controls for keeping all parts of the system working together smoothly. . . . After weighing the advantages and disadvantages of both auger conveyors and high-volume, low-pressure pneumatic conveyors, these engineers selected for their tests a low-volume, medium-pressure pneumatic conveyor, which they arbitrarily define as a system employing not more than 20 pounds of air pressure per square inch. Such a system is said to have these advantages over a high-volume conveyor: It causes much less dust at the discharge location; it requires a smaller pipe, and it produces more air pressure. Another thing, since less air is moved at higher pressures, more useful work can be accomplished with a given amount of energy. . . . The medium-pressure system is suited to automatic feed distribution for the reason that it is easily installed and controlled, and feed can be routed from one loading point to another of several discharge locations. Also, since valving and piping systems have been developed for commercial applications, similar equipment can be adapted for farm use. . . . Laboratory studies have been made on the effects of a number of variables, including diameter of conveying pipe, length of system, volume of air moved, rate and direction of conveying, type of material conveyed, elbow radius, and orientation and location of elbows. The engineers conclude from their studies, both at the farm and in the laboratory, that feed distribution can be completely automatic and as convenient as piped running water.

Tell him how to cut milk production costs

As you know, the housing of dairy cows is a major expense in milk production. Naturally, farmers are quite interested in cutting this expense. U.S. Steel, in cooperation with the University of Wisconsin, studied the problem in *The Dairy Barn Research Project.* The findings were reported to farmers across the country and after a trial period here is what they are finding: a loose housing system makes the most economical and efficient type of dairy operation. Milk production cost per cow goes way down because loose housing saves time, labor costs and capital investment. And the herds stay a lot healthier, too, because a loose housing system is much easier to keep clean.

It's a good idea to have farmers visit operating loose housing systems *before* they decide to switch to loose housing. This will give them a look at how it works and what they'll need to make it successful.

For complete information, have farmers send for U.S. Steel's free book, *Loose Housing.* United States Steel, Agricultural Extension, 525 William Penn Place, Pittsburgh 30, Pennsylvania. *USS is a registered trademark*

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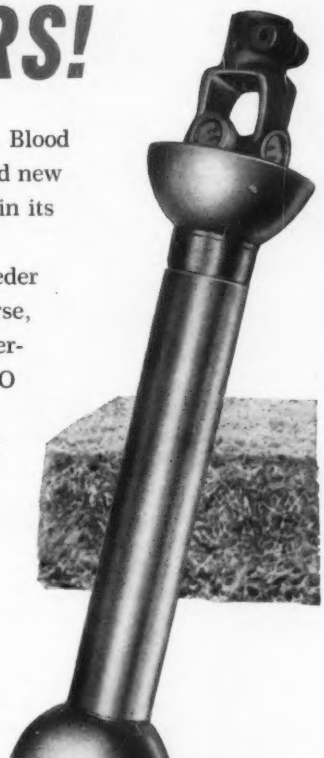

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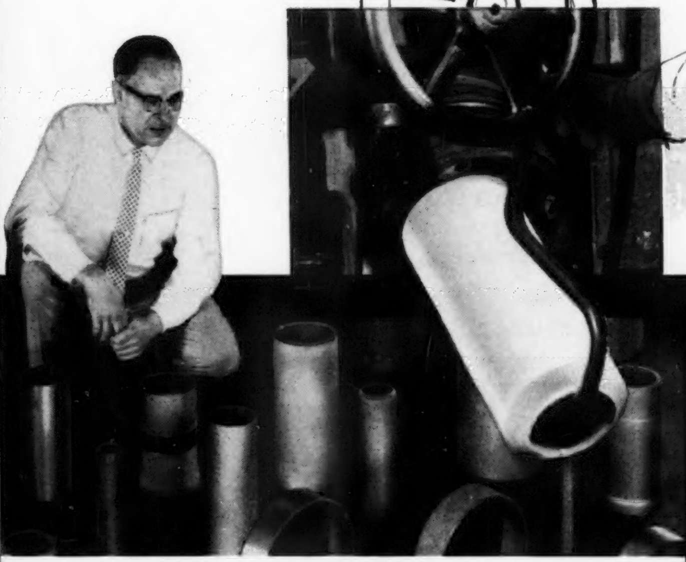

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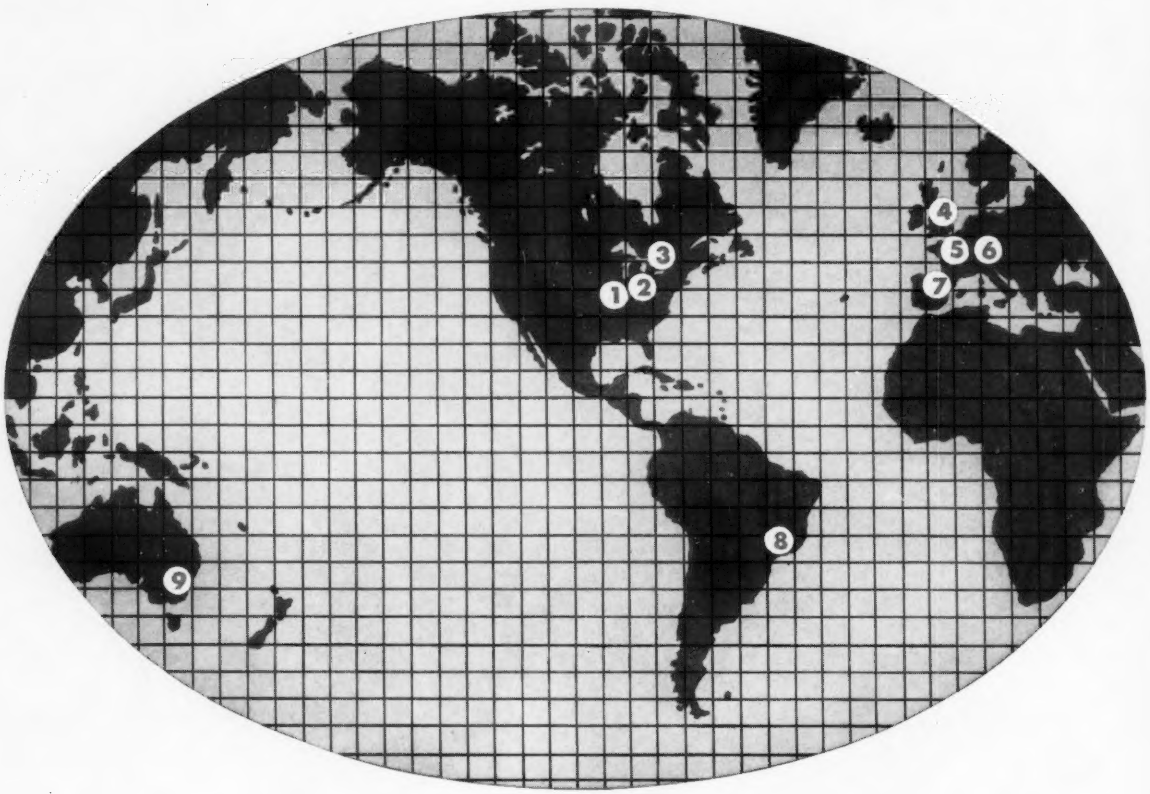

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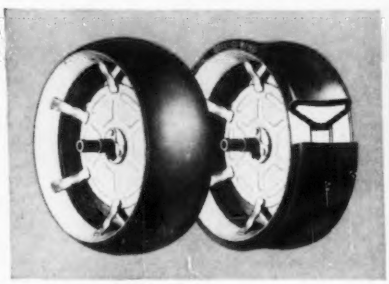

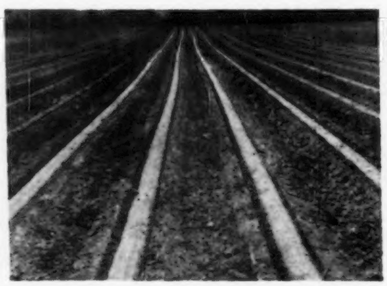

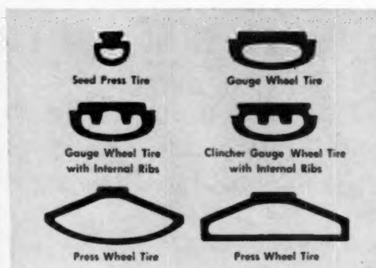

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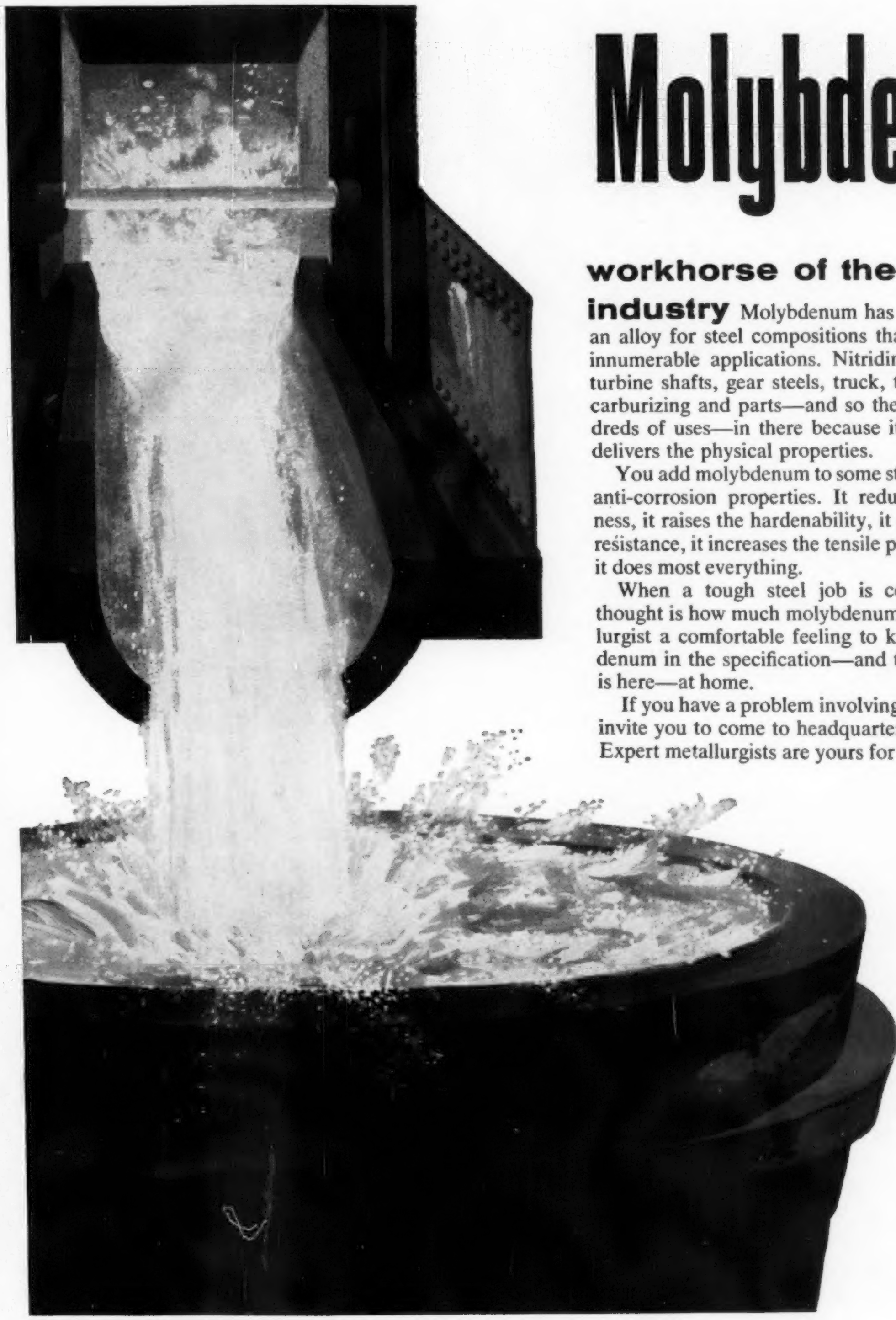

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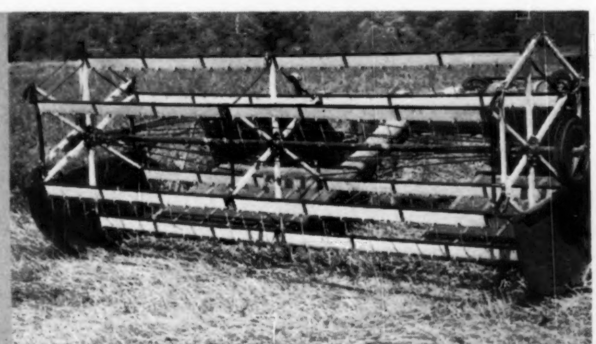

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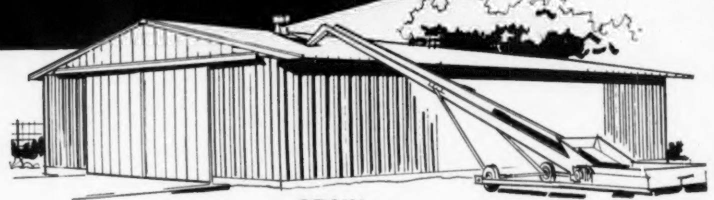

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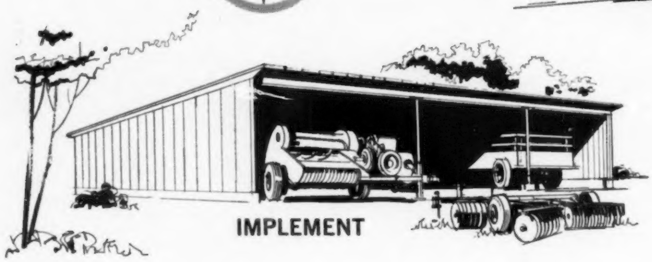

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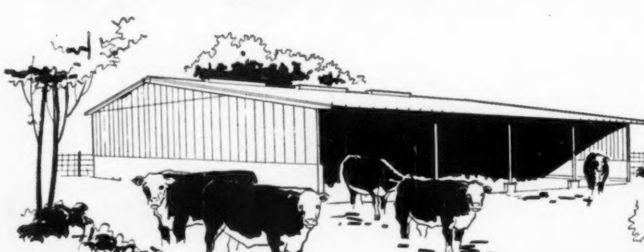

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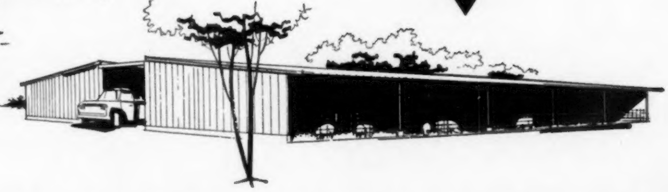

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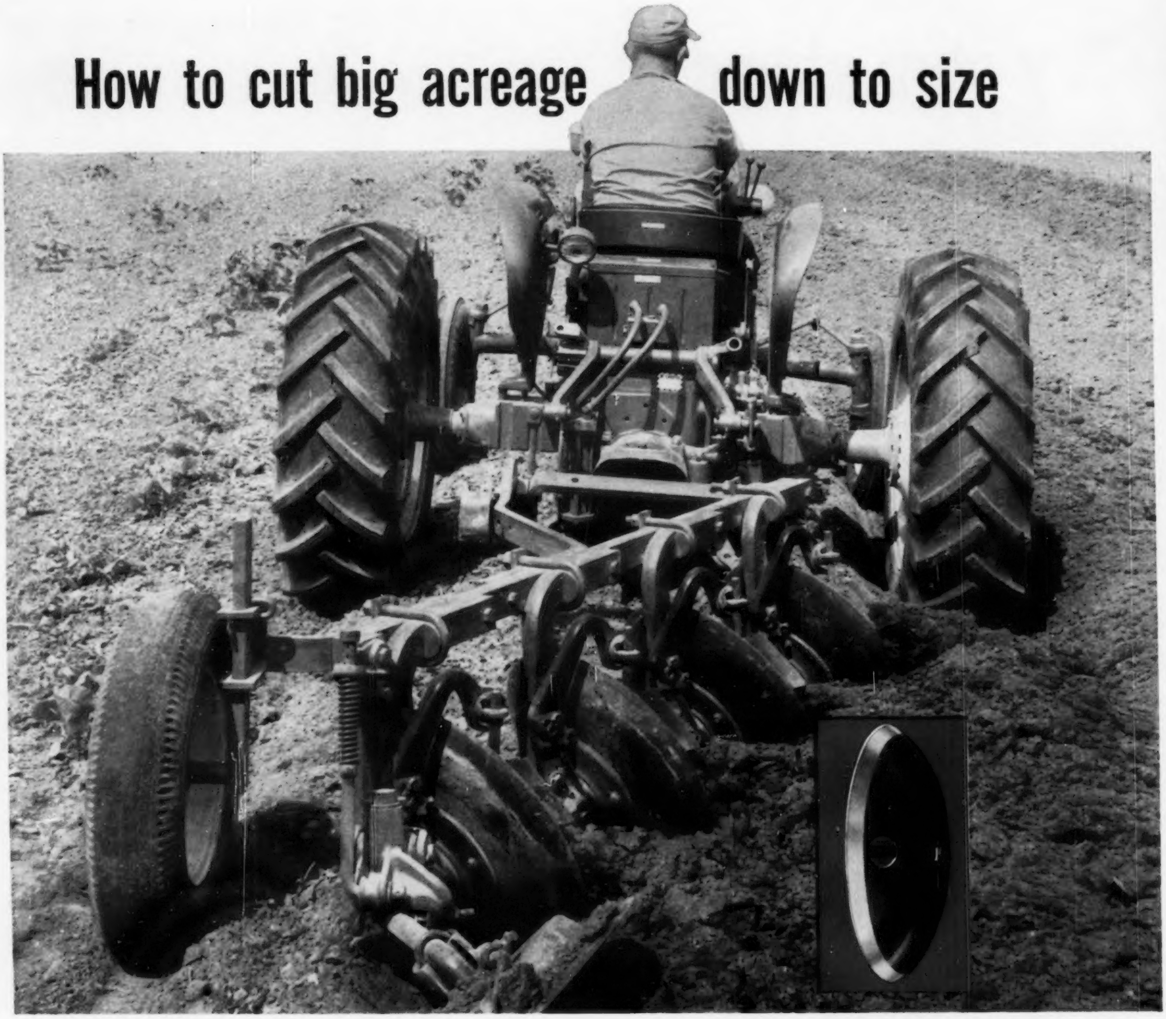

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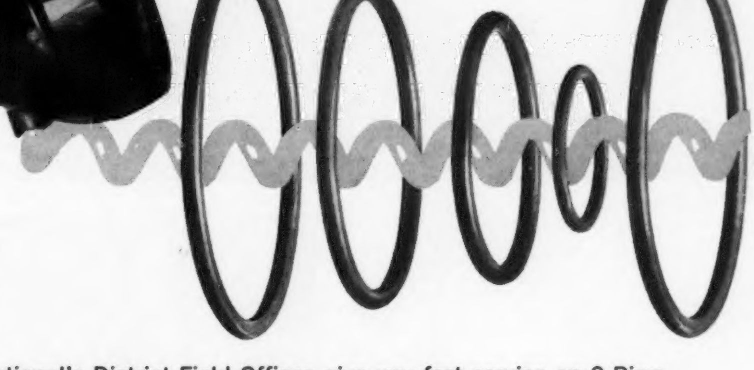

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Agricultural Engineering

September 1960
Number 9
Volume 41

James Basselman, *Editor*

About the Farmstead Engineering Conference

THIS issue of AGRICULTURAL ENGINEERING has been established as a "special" and features the proceedings of the ASAE-Sponsored Farmstead Engineering Conference on Confinement Housing of Livestock held September 13 to 15 at the University of Illinois. Each paper presented during the conference is published in its entirety, and other related materials have been included to make this issue a comprehensive handbook on the subject, suitable for the engineer, manufacturer, dealer, and the farmer alike.

The three-day conference has as its theme, "Engineering – The Key to More Efficient Livestock Production," and is sponsored by the ASAE Farm Structures Division, in cooperation with the Agricultural Engineering Research Division, ARS, USDA, and departments of Agricultural Engineering and University Extension, University of Illinois. The Committee for Farmstead Engineering Conference is composed of E. L. Hansen, (chairman), E. D. Anderson, S. S. DeForest, C. F. Kelly, C. W. Hall, M. W. Forth, and K. H. Beauchamp.

The purpose of the conference is to collect and disseminate the most current information on all factors affecting confinement housing of livestock and to summarize and bring into focus basic and functional design requirements relating to engineered farmstead and housing systems. Its objectives are: (a) To present the most advanced information from the standpoint of management, breeding, feeding, sanitation, marketing, and other future considerations which may affect farmstead engineering; (b) to present basic and functional requirements of animals in a way that is useful to designers; (c) to present design procedures and solutions for combinations of components for economical operation; (d) to point up areas in which basic research is needed; (e) to focus attention on cost vs. returns of engineering housing systems; (f) to focus attention on power requirements of engineered farmsteads; and (g) to publish this material in a special issue of the Journal for easy reference.

The program consists of a total of 22 talks in four livestock areas – poultry, swine, dairy and beef. Keynote speakers have been selected for each area as follows:

Poultry: Dr. T. C. Byerly, deputy administrator of the Agricultural Research Service of USDA.

Swine: Dr. O. Burr Ross, head of animal science department, University of Illinois.

Dairy: Dr. Woodrow Snyder, department of dairy, Michigan State University.

Beef: Dr. Albert E. Darlow, vice-president of agricultural sciences, Oklahoma State University.

In each livestock group papers have been prepared to cover the functional and basic requirements of housing; and likewise, papers have been prepared to cover the combination of components for economical operation. In order to assist the reader, papers are printed by animal groups – Poultry starting on page 566; Swine on page 584; Dairy on page 594; and Beef on page 611. The keynote talk leads each group and is followed by one or more papers on functional and basic requirements of housing and one or more papers on combination of components for economical operation. Subheads and continued lines are designed to help identify the various categories and to maintain uniformity of information between animal groups.

Following the papers by animal groups are four papers dealing with the costs and benefits of engineered farmsteads; capital requirements; future power requirements; and electric power supply. These articles begin on page 622. As an added feature a table of Apparent Densities of Dry Feed Ingredients was reprinted from *The Feed Bag Red Book* for 1959.

In order that our readers might be informed of the latest "Manufacturers' Literature" which describes components, equipment or systems especially adapted for farmstead engineering applications all known manufacturers of such equipment were invited to furnish a list of their own available material. In the interest of saving space the literature is listed on page 634 by subject matter with a code number to identify the manufacturer. An alphabetical list of manufacturers appears on page 636. Copies of the literature listed may be obtained by writing to the manufacturer whose complete address is given.

Although not part of the Farmstead Engineering Conference, but of related interest, is a report of a recent meeting of the Production and Marketing Department of the Farm Equipment Institute. The report, supplied by A. B. Skromme, program chairman, presents an up-to-date story on the developments in the mechanization of farm materials handling with special emphasis from the point of view of industry. It seemed to be most appropriate to present this report in this special issue, page 638, since the September 1958 issue carried the proceedings of the first ASAE-sponsored conference on Farm Materials Handling.

In anticipation of a heavy demand for additional copies of this issue we have increased the press run and copies will be available from ASAE, 420 Main St., St. Joseph, Mich., at $1.25 per copy (10 or more copies, $1.00 per copy).

ASAE Winter Meeting • Peabody Hotel, Memphis, Tennessee • December 5-7, 1960

POULTRY

Goals of Engineering Research on Poultry Housing

T. C. Byerly

WHAT is it we seek to accomplish through engineering research on poultry housing? First, basic research must provide the physical and much of the physiological data on heat and gaseous exchange needed to make life of poultry in a restricted environment possible.

Second, engineering research on poultry housing must provide much of the physical data and aid in determining the physiological data on heat, gaseous, and water exchanges, and on light, temperature, humidity, and air movement in optimal and also less-than-optimal but acceptable environments; and devise structure-equipment complexes that will dependably produce such environments.

Third, it must provide information which will lead to the provision of housing at lowest sustained cost in terms of cost per unit of production. A corollary is that housing must in some measure meet the convenience of operators and the social habits and health requirements of poultry.

Traditionally, poultry used existing space and labor not required for other purposes on general farms. In the absence of refrigeration and with infrequent trips to market towns, poultry and eggs were the principal sources of fresh meat for the farm family. In a very real sense, returns from poultry were all net. No money was spent for feed, for chicks, for housing, nor for labor. The place of poultry in farm subsistence is still important but continually diminishes. However, more than 25 percent of the farm-produced chickens are still consumed on farms, which may be compared to about 10 percent of milk and eggs. Traditional poultry production was highly seasonal. Winter was a non-productive, survival period.

The traditions of poultry production are responsible for some presently widely held opinions—some sound, some unsound. One of these is that any healthy, industrious person of sound mind provided with appropriate feed, facilities and stock can produce poultry efficiently. This view continues to be expressed in the development of new integrated broiler, egg and turkey enterprises. In the old days it was a major factor in the establishment of Petaluma, Vineland, and other poultry communities.

This view is now, as always, half true. It has been amply demonstrated that some operators produce poultry successfully and consistently and others do not. There is no high correlation between degree of success and any set of observable practices or previous training or experience. Poultry have been produced successfully in very crude and apparently unsuitable structures. Failures have occurred in the presumptively best facilities.

Research on poultry management, with the most rigorous control of practices tested, with quantitative measurement of interaction of practices within various environments, is badly needed.

Another important traditional view widely held among poultry producers is that value of facilities should be ignored in determining current costs and returns. Since facilities designed to house poultry are ill-suited for other use, the practice of charging them off at once and calculating costs and returns on a cash operating basis is realistic. It may also be, or ought to be, a deterrent to excessive costs of new facilities.

Housing costs can be justified only as they result in lower operating costs or increased production. Stewart and Hinkle (1959) have pointed out that housing conditions which will keep litter dry at a population density of one layer per square foot may actually reduce housing cost per layer, even though construction and equipment cost per square foot for such housing is higher than simpler construction permitting only the traditional one layer for each 3 sq ft of floor space. Cost per dollar value of production is the first factor, the persuasive factor, the compelling factor in poultry housing. The standard which engineering research and development in poultry housing must meet is: will it pay? Poultry housing ought to be functional. Research is finally making it so.

Only a crude estimate of investment in poultry housing can be made. The USDA's "Farm Costs and Returns," AIB No. 230, contains data for only one type of poultry farm. It gives estimates of value for land and buildings and for machinery and equipment on New Jersey commercial poultry farms. Data for such farms probably show the same trends as for other types and other areas. These are egg farms, family farms. Average estimated value of land and buildings in the 1947-49 base period was $22,850, or about $7.80 per layer on hand during the year. In 1959, land and buildings were estimated at $45,150, or about $10.60 per layer on hand. Land is a minor factor, principally a building site and home site convenient to market. Machinery and equipment per farm in the 1947-49 period was $1,110, or about 40 cents per layer, and in 1959, $1,930, still about 40 cents per layer. Net annual cash cost for buildings and machinery was about 40 cents per layer. A crude expansion of the estimates to cover all layers in the United States gives us a current estimate of about $3.5 billion for land, buildings, and machinery and equipment used for all laying flocks, $1 billion for commercial broilers, and $500 million for turkeys, or a total of about $5 billion. This guess is surely no greater than replacement cost. It is much greater than cost of acquisition.

The costs and returns series provide more important statistics from the standpoint of efficiency. On the basis of 1947-49 = 100, average operating expense per unit of production for the 1949-58 period was 91, and for the year 1959 only 81. Total cost per unit of production was 94 for the 1949-58 period and 87 for 1959. These indices are the lowest among all thirty-two types of farming included in the costs and returns series. So was the index for net farm income for these egg farms. In the 1947-49 base period, investment in land, buildings and machinery averaged about $24,000 and cash receipts about $26,000, clearly exceeding the fixed investment. This relationship

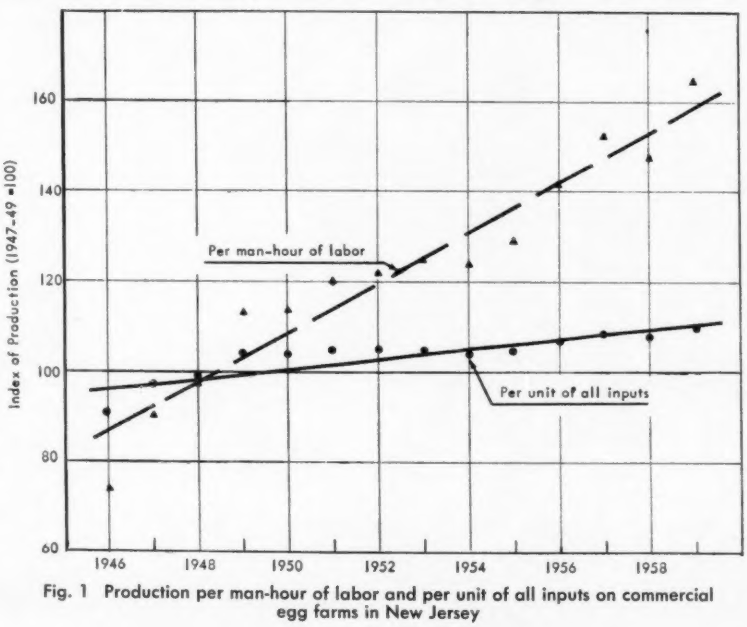

Fig. 1 Production per man-hour of labor and per unit of all inputs on commercial egg farms in New Jersey

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reflected a healthy economic relationship. In 1959, cash receipts were only about 50 percent of estimated worth of land and buildings. If present prices for eggs and poultry continue, it is my opinion that costs for buildings and equipment per layer, broiler, and turkey must be reduced.

One way to make housing per bird cheaper is to increase the population per unit area and this the application of engineering and biological information is achieving. The old rule that a Leghorn layer required 3 sq ft of floor space is gone. A well-designed and equipped house can cut that space allowance just about in half. This won't cut cost per layer in half, but it may cut it some and improve labor efficiency too.

Engineering research leads in some measure to mechanical control and mechanical operation. It often leads to increase in scale in order to spread total cost over a larger number of production units and thus maintain or reduce unit cost. Engineering research may increase man-hour output; it may reduce labor requirement. If the latter, is there available to the farmer alternate uses for the labor eliminated? Reduction in man-hour requirement and increase in man-hour output are in part only apparent because labor used in fabrication, formulation and construction is substituted for the obvious directly applied labor of the farm operator. Currently off-farm labor is more highly paid than farm labor so that the curves shown in Fig. 1 for man-hour output and production per unit input are to me impressive. Even at 1.4 hr per layer, as shown for 1959 for the New Jersey costs and returns flocks, and a dollar an hour for labor, direct on-farm labor would constitute only about 20 percent of the cost of egg production.

Poultry-flock size continues to increase. Flocks in the costs and returns series have increased from an average size of 2,163 layers in 1946 to 4,212 in 1959. While chickens are kept on about 3 million farms in the United States, only about 80,000 flocks of the size of these in New Jersey would be needed to produce our current egg supply.

These are family farms. They used 4,080 hours of operator and family labor in 1946, and this increased to 4,900 hours in 1959. Hired labor fell from 1,280 hours in 1946 to 800 hours in 1959. Labor efficiency increased greatly, as shown in Fig. 1. On the basis of 1947-49=100, physical units of production per hour of labor increased from about 90 in 1946 to about 160 in 1959. These farmers work efficiently. Using the laying hen as the production unit for calculation purposes and attributing all labor to the layers, hours per layer kept fell from 2.5 in 1946 to 1.4 in 1959. Egg production per layer increased during the period so labor time per dozen eggs produced was reduced even more sharply. However, net farm income, which averaged $4,689 per year in the 1946-50 period, fell to $1,775 in the 1955-59 period. It is noteworthy that while man-hour output increased about 80 percent during the 1946-59 period, production per unit of all inputs increased only about 15 index points, from 95 in 1946 to about 110 in 1959.

Our knowledge of the physical requirements for poultry of different ages and species has accumulated over the past thirty years. The work of Barott and Pringle (1946) began about 1924 with the incubating egg and continued in later years to give us basic data on heat production and gaseous exchange for chickens of all ages. Wallace Ashby and his associates (Ota, Garver and Ashby, 1953) have contributed a great deal of information on requirements under simulated laying-house conditions. Environmental laboratories at Purdue, University of California, and other state and federal stations will extend our knowledge of physical environment requirements. In spite of long-established application of light supplementation in egg production and more recently in turkey production, we are woefully lacking in quantitative data on the relation of periodic, qualitative and quantitative light variations on growth and reproduction and feed efficiency in poultry.

Engineering research and its application will provide poultrymen with housing in which environment can be maintained uniformly or altered at will or by program schedule. One environment is provided for the flock within which each bird makes its own microenvironment. Chickens and other poultry are social creatures; they huddle together in a cold environment. They establish their own social order when permitted to do so. Direct contact and indirect contact through air and drinking water provide ready means for disease transmission. The relation of environment to severity of disease and to transmission is very imperfectly known. There is real need for the laboratories to be constructed at Athens, Ga., and Mississippi State University for research on environmental factors affecting poultry disease transmission and expression. Poultry husbandmen, veterinarians, entomologists, parasitologists, and microbiologists will work as teams with physicists and engineers.

I have talked about cost of production per unit of output; others will consider engineering *per se*. I have referred to need and opportunity to do research on the relation of environment to poultry health. I wish to make one final reference to the chickens, turkeys, and other poultry for which housing is to be provided. The art of poultry husbandry is neglected. Many sciences and technologies are replacing it. Instead of poultry husbandmen in the traditional sense we are training behavioral scientists, climatic physiologists, geneticists, nutritionists, ecologists, immunologists—and engineers. Collectively, they know and can demonstrate that they know far more about poultry than the poultry husbandman ever hoped to know. But, as we reduce the amount of human time and labor, we lose flexibility. The machine and the system may be programmed to signal trouble but the best they can do to meet it is to stop. Brains, judgment, even intuition are still necessary components if the best engineered buildings, equipment, and systems are to operate efficiently.

This conference is most timely. The fine papers to be presented by A. D. Longhouse, Merle Esmay, Fred Stephan, L. N. Drury and D. O. Baxter will provide not only concise evaluations of the current status of engineering information on poultry-house requirements and design but will also provide stimulus and guides for research planning.

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Heat and Moisture Design Data for Poultry Housing

A. D. Longhouse, Hajime Ota, and Wallace Ashby

Member ASAE *Member ASAE* *Life Fellow ASAE*

INCREASED production from poultry per man-hour of labor, per dollar of investment and per unit of operating cost require *(a)* the most favorable response from the birds and *(b)* the most efficient use of human labor, buildings and equipment. Engineering research and development contribute directly to both of these objectives.

This paper is concerned principally with the first objective, that is, the control of ambient air conditions in shelters that will induce favorable response from the birds and result in a high-quality product.

Designers of poultry houses and ventilation systems have been handicapped by lack of adequate data on the heat and moisture production of the birds. Mitchell and Kelley (1)* assumed the extra heat due to voluntary activity to approximate one-half

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Authors' Note: Some of the data comprising this paper were obtained from research supported in part by regional funds for NE-8: "Essentials of Poultry Housing for the Northeast," a cooperative study involving states of the Northeastern region of the United States and the Agricultural Research Service, USDA.

*Numbers in parentheses refer to the appended references.

the basal heat. Data presented by Barott and Pringle (2) determined the latent and sensible heat production at basal metabolism conditions. These values do not correspond to those found in calorimeter tests with laying hens.

The main part of this paper deals with ventilation and moisture removal of laying houses in cold weather, *(a)* because of its importance in poultry house management and *(b)* because we have new data to present on heat and moisture production of laying hens and broilers that will be useful in designing poultry houses and ventilation systems.

Because of limitations of time and space for publication, the requirements of poultry for floor and equipment space, light, temperature, and related factors are summarized in the appendices to this paper.

Limitations of Ambient Conditions in a Laying House

Temperature and Relative Humidity. In winter the warmer and drier the shelter, the less the complications of wet litter, disease, dirty eggs, and building deterioration encountered.

Ideal ambient temperature for all breeds may be near 55 F. Most breeds begin to show signs of low temperatures stress below about 45 F by increased feed consumption and sensible heat production. Thus the minimum design temperature should be near 45 F and the maximum relative humidity 80 percent. To maintain good conditions the bird population should be kept near the maximum for which the house is designed.

The maximum summer design condition for light breeds (such as Leghorns) should be 90 F and 70 percent relative humidity and for heavier breeds (such as Rhode Island Reds) 85 F and 70 percent relative humidity. For older hens (more than 12 months of age) the maximum design temperature for summer should be lower by about 5 F.

For winter use the house should be insulated, to permit removal of at least the respired moisture while maintaining the house temperature at 35 F or above. The ventilating system should have capacity and flexibility to dry out the house during warm periods and to maintain desired temperature in winter.

Under usual housing conditions, both temperatures and relative humidities vary considerably. Information on temperature duration (in combination with humidity) effects on poultry are not available. Squibb (3, 4) found from field studies that short daily periods of high and low temperatures have little effect on production of laying hens. There are studies under way to determine the effects of diurnal temperature fluctuations.

Litter Moisture Content. The amount of dust in the air increases when the litter moisture content decreases below 20 percent wet basis. An excessive amount of moisture in the litter soils eggs and contaminates feeders and waterers. However, the maximum amount of litter moisture should not exceed about 40 percent on a wet basis (sawdust litter), as the litter tends to "cake over" with increased water content. Beltsville studies show that ammonia production from litter decomposition (sawdust) will commence at 17 to 19 percent moisture content on a wet basis at temperatures above 32 F. The design should aim to keep moisture content of litter below 33 percent wet basis.

Tolerable Limits of Ammonia. Ammonia can be detected by humans near 10 to 15 ppm and near 50 ppm eyes begin to water. Scarborough (5) showed that exposure to 50 ppm in the air for 10 days will affect growing chickens. Beltsville studies showed that hens may be able to withstand about 40 ppm.

The ventilation system should keep ammonia concentration below 40 ppm over a prolonged period. Conditions disagreeable for the caretaker probably are not good for poultry. Since ammonia is about one-half as heavy as air (air density at 0 C is 1; ammonia is 0.596), assess ammonia concentration near bird level.

Importance of Ventilation. While ventilation is necessary to supply oxygen and to remove noxious gases and airborne material, its most important function is to regulate the levels of temperature and moisture in the building. Good temperature and moisture control in winter require *(a)* house construction suited to climatic conditions, *(b)* proper rates and distribution of ventilating air, and *(c)* means for removing or temporarily storing moisture, or *(d)* use of supplemental heat during cold periods. The amounts of insulation and the ventilation rates for a poultry house under various climatic conditions can be calculated with reasonable accuracy if the heat and moisture given off by the chickens are known.

Dust. Dusty environment has at least two bad effects (6): *(a)* it serves as a vehicle to transport disease-producing organisms and *(b)* high dust concentration may irritate tissues which ultimately become susceptible to disease organisms.

The effect of various pollutants on many human chronic ailments have not yet been established (7).

Studies to Control Disease. Recent federal legislation to study broiler diseases in a controlled laboratory environment in Georgia and, under simulated farm conditions, in Mississippi may result in much-needed information on the health standards for poultry.

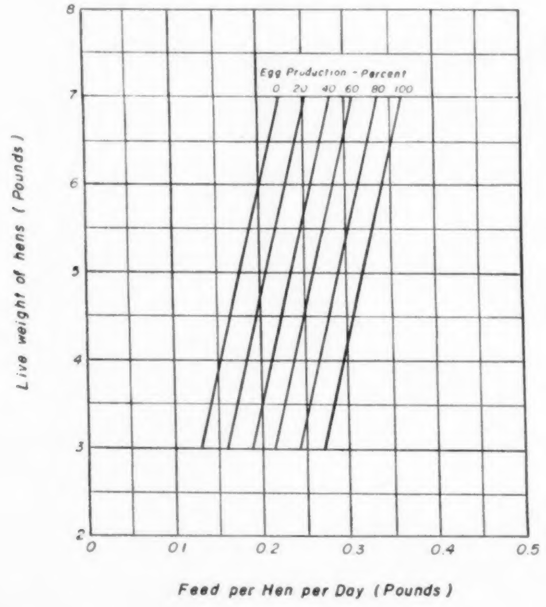
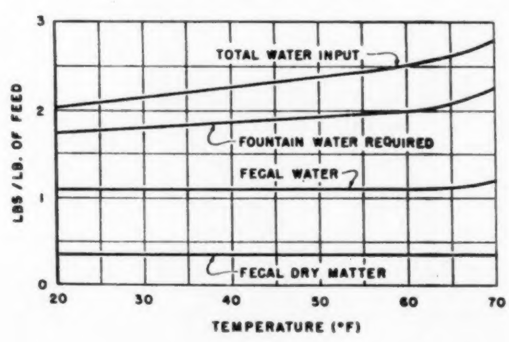


Fig. 1 *(Left)* Daily feed requirements for hens of varying weight and egg production rates (10)

Fig. 2 *(Below)* Water and fecal material per pound of feed consumed by White Leghorn hens



Calculations for Moisture Control

The moisture released in the poultry laying house depends on the size and breed of hen, rate of egg production, and the density of hen population. Standard weights of hens of different breeds may be found in Table 1. Heat and moisture calculations should be based on pullet size. The house will of course be designed for hens laying at a high rate, for this is when they consume maximum feed and water and therefore give off the most moisture.

TABLE 1. STANDARD BODY WEIGHTS OF VARIOUS BREEDS OF LAYING HENS

Breed	Mature hen, lb	Pullet,* lb
S. C. White Leghorn	4.5	4.0
Rhode Island Red	6.5	5.5
New Hampshire	6.5	5.5
White Plymouth Rock	7.5	6.5
Cornish	8.0	6.5

* Less than 12 months old.

Water Input. The feed requirements of poultry are directly related to the weight of the bird, ambient temperature and rate of egg production. Byerly (8) developed the following equations for annual feed requirements for the laying hens:

For Leghorns: (15 times body weight in pounds) plus (number of eggs divided by 8) equals total annual feed consumption in pounds.

For New Hampshires: (13 times body weight in pounds) plus (number of eggs divided by 8) equals total annual feed consumption in pounds.

Fig. 1 was developed from Byerly's equations. The estimates agree quite closely with results obtained in the calorimeters at temperatures between 40 and 75 F, but are as much as 100 percent higher than the calorimeter results at temperatures above 85 F, and 10 to 15 percent low at temperatures below 40 F. For design purposes, feed consumption should be based on 75 percent egg-production rate.

TABLE 2. CONSTANTS FOR DETERMINING WATER CONSUMPTION, FECAL AND WATER ELIMINATION IN RELATION TO FEED CONSUMPTION

	Ambient Temperature			
	20 - 40 F	40 - 60 F	60 - 80 F	80 - 100 F
Water to feed ratio (9)	1.5-1.7	1.7-2.0	2.0-2.5	2.5-5.0
Water plus feed to feces ratio (9)	1.7	1.7*	1.8*	1.9*
Percent water content of feces (9)	75	75	77	80
Percent water content of egg (9)	65	65	65	65
Size, ounces per dozen	24	24	24	24
Percent free, hygroscopic and metabolizable water in feed (9)	54	54	54	54
Approx. heat of vaporization (Btu per lb)	1100	1100	1100	1100
Ratio of respired water to water input	0.30-0.33	0.33-0.40	0.40-0.45	0.45-0.55†
	0.22-0.35	0.35	0.35-0.42	0.42-0.55‡
	0.25	0.25-0.35§	-----	-----

*For White Leghorns add 0.30 to these values.
†S. C. White Leghorn hens.
‡Rhode Island Red hens.
§New Hampshire and Cornish hens.

Metabolized water from feed was estimated by Mitchell and Kelley (1) at about 48 percent of the weight of the dry matter in the consumed feed plus the free and hygroscopic water in the feed. Ota (9) uses 54 percent (wet basis) weight of feed as the weight of water released when the feed is digested. This assumes that the ordinary moisture content of feed is 10 percent.

The quantity of fountain water consumed by poultry depends on body weight, physical activity, rate of egg production and ambient temperature. For example, laying hens consumed about 1.5 to 1.7 times as much fountain water as feed at relatively low temperatures (20 to 40 F) and about five times as much water as feed at temperatures near 100 F.

Water Output. The water output from the hen includes the water that is respired, the water in the feces and the water in the eggs. Table 2 presents constants for determining water consumption and fecal and water elimination in relation to either feed or water input at various temperature levels. Knowing either the water or feed consumption and these ratios, the amount of feces can be calculated. Fig. 2, based on Table 2, presents data for White Leghorn hens.

In houses using litter there may be additional moisture (and heat) from litter decomposition. Very little information is available concerning litter decomposition.

Heat Production

The quantity of heat produced by chickens depends upon breed, size, age of hen, and environmental temperature.

The total heat production per pound of live weight was reported by Ota (9) for White Leghorn and Rhode Island Red hens at temperatures of 25 to 94 F (Fig. 3). At constant temperature, total heat production per pound of live weight decreased as body weight increased. When temperatures

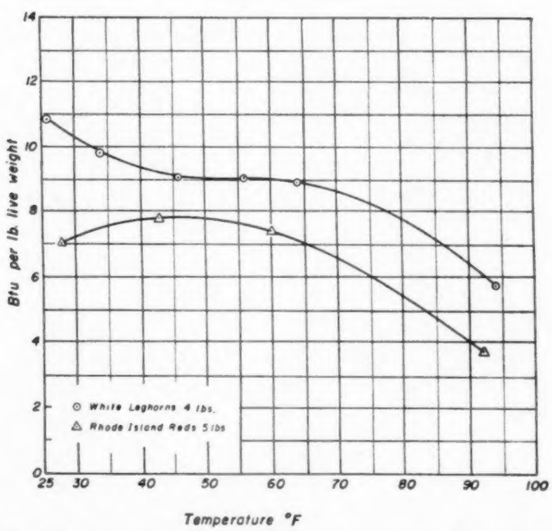


Fig. 3 Total heat produced by caged layers per pound of body weight in relation to ambient temperature

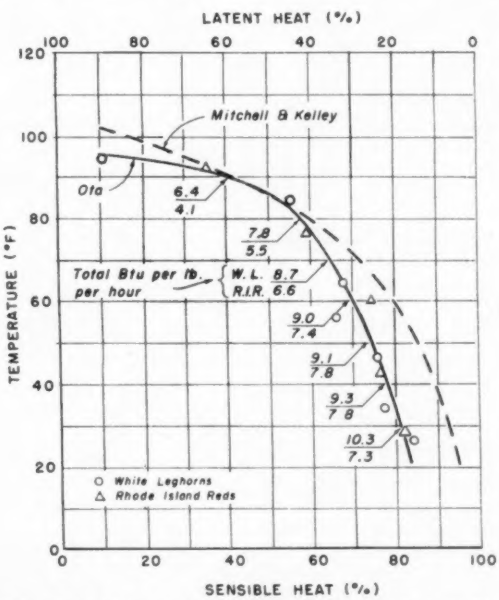


Fig. 4 Total heat per pound of weight and percent of sensible and latent heat produced by caged layers in relation

varied (25 to 94 F) total heat production per pound of body weight was largest in the moderate temperature range (40 to 60 F) for the heavy breed (Rhode Island Reds) and dropped at extreme temperatures, either cold or hot. This was not true for the light breed (White Leghorns) at lower temperatures. Heat output leveled off in the moderate temperature range (40 to 60F), then increased at lower temperatures.

In using these data it should be kept in mind that no other type of farm livestock can vary in metabolism as much as the hen. At temperatures below 35 F, birds can voluntarily alter their body insulation and exposed area by fluffing feathers and covering their heads under their wings. The daily variation in heat production may easily change as much as 15 to 25 percent.

Fig. 4 gives further information on heat production of hens, the solid line being plotted from Ota's data (9) and the dotted line from Mitchell and Kelley's equation (1).

The latent heat percentage varies widely with the temperature. For example, using Ota's data, at 90 F about 60 percent of the total is latent heat (40 percent sensible heat), while at 20 F the latent heat production is only about 15 percent.

The amounts of total heat per pound of live weight for both Rhode Island Reds and White Leghorns are shown by the figures at the left of the solid curve. For instance, at 60 F the light bird produces about 9.0 Btu per pound (live weight) per hour while the heavier bird produces 7.4 Btu per pound per hour.

Beltsville studies show that at the beginning of a study at low temperatures, the metabolism was nearly 50 percent of total heat obtained a week or ten days later at the same temperature. A sudden drop in temperature in a poultry house may cause a similar drop in heat production. Deighton and Hutchinson (11) reported that standing hens produce 40 to 45 percent more heat than when they are sitting.

It should be noted that tremendous strides have been and are still being made in breeding, diet, and other means to speed up and increase production of meat and eggs. Thus data obtained a few years ago may need revision.

Factors Affecting Heat and Moisture Control

In applying the basic data to poultry-house and ventilation-system design, it should be understood that hens do not produce enough heat to enable ventilation during cold weather to remove moisture at the rate it is given off in the respired air and the feces. For example, in an ordinary house at 55 F a 4-lb White Leghorn hen laying at 65 percent gives off daily about 865 Btu of heat and 0.61 lb or 4270 grains of moisture. Thus the ratio of grains of moisture to Btu of heat would be 4.9 to 1 if no heat were lost from the building by conduction. To remove the moisture as it is given off, the ventilating air should pick up 4.9 grains of moisture for each Btu of heat gained from the house. Reference to a psychrometric chart will show that this ratio cannot be obtained if the outside air is even 5 F cooler than the house unless the air is very dry, that is, relative humidity below 50 percent. On the other hand, if the condition of entering air were 0 deg F, 80 percent relative humidity, the ratio of grains of moisture to Btu of heat removed would be 2.66 to 1, which is about sufficient to remove the moisture in the respired air but not that in the droppings. This should be the minimum design requirement.

To maintain satisfactory temperature and moisture conditions in winter, it is necessary either to increase the heat available or to reduce the amount of moisture to be removed by ventilation. The following factors aid in solving this problem:

(a) Litter and Feces Store Moisture. The more litter there is in the house, the more moisture from the droppings can be stored during cold weather and then released during a warm spell.

(b) Value of the Mechanical Pit Cleaner. The mechanical pit cleaner is as important as mechanical ventilation to the proper maintenance of environmental conditions in the large poultry house. It not only saves labor, but it removes large quantities of water. A month long study at the West Virginia Agricultural Experiment Station, May 22 - June 28, 1959, revealed that approximately 75 percent of the droppings voided in the windowless and solar houses fell into the pit. The droppings contained 60 percent moisture (wet basis) at the time they were removed from the houses. With about 400 hens in the house, the pit cleaner removed 39 lb of water daily.

(c) Heat from electric lights, brooders, and motors supplements heat from the hens and may be important.

(d) Solar energy is a source of supplemental heat for poultry houses with large south windows. The amount of solar energy reaching the earth's surface in Zone 2 (West Virginia) is 500 to 600 Btu per square foot daily during December and January.

(e) The larger the shelter, the less exposed area, and therefore the less conduction heat loss per bird housed. Also the larger the shelter, the more capacitance or "flywheel" effect to maintain temperatures higher than outside. Thus, the heat stored from warmer days in building material, litter, and from the ground is released during a cold spell.

(f) Adiabatic Removal of Moisture During Warm Spell. It is customary for poultrymen to open up the house during a warm spell in winter to dry it; as they say, "air it out". During these intervals heat from the birds is supplemented by the heat released in cooling the air to the wet-bulb temperature. For example, assume that the outdoor temperature is 55 F, the relative humidity 40 percent and that the exhaust air relative humidity is 70 percent; then about 10 grains of moisture per pound of dry air will be removed, and the temperature inside the house may drop. This procedure is similar to drying hay or corn with unheated air. For rapid drying a large amount of air must pass through the house.

(g) Poultry like any other heated body loses energy continuously by radiation. In the winter, thermal radiation losses should be minimized. In the summer, thermal radiation should be encouraged.

(h) The calculated U value for the house may not be the true U value for all seasons of the year. If moisture accumulates in the building material (including insulation) the U value may become higher than if no insulation were used, thus hindering the calculation of heat losses. Minimum U values of insulation would likely occur during the summer.

Results of humidity testing in walls as reported by Henriksson (12) show that, so far as inorganic materials are concerned, very little drying takes place during the heating season. The amount of humidity in

TABLE 3. EXPERIMENTAL DATA FROM SOLAR AND WINDOWLESS POULTRY HOUSES AT WEST VIRGINIA UNIVERSITY AGRICULTURAL EXPERIMENTAL STATION

	April 4 - 10, 1959		Jan. 30 - Feb. 5, 1960	
	W.H.	S.H.	W.H.	S.H.
Temperatures, deg F				
Inside —				
Dry bulb	64.3	64.0	54.4	55.5
Wet bulb	55.7	57.0	50.5	51.6
Outside —				
Dry bulb	58.9	58.9	39.3	39.3
Wet bulb	50.3	50.3	36.4	36.4
Fan				
Percent operation	77.0	63.0	30.8	39.3
Kilowatt-hours per week	45.0	43.0	17.0	33.0
Lights				
Kilowatt-hours per week	87.0	5.0	136.0	126.0
Litter moisture				
Percent wet basis	26.5	28.7	46.0	34.0
Hen				
Bird number	430.0	406.0	445.0	456.0
Per cent egg production	62.0	67.0	68.0	75.0
Total heat, btu per hour per hen	35.6*	35.6*	34.0†	34.0†

*4 - lb hen
†3.75 - lb hen

the walls remains the same, but is rearranged in such a way that the outside is wet and the inside is dried. Additional investigations should be made.

(i) Moisture Changes in Structure and Dust. Wooden items, dust, and construction material, with the exception of metallic objects, act like a sponge, absorbing or giving off moisture, when vapor pressure within the shelter changes.

The Application of Basic Data

The validity of the basic data set forth in this paper was verified by applying them to the experimental windowless (WH) and solar (SH) houses at the West Virginia Agricultural Experiment Station, Morgantown. The houses are described in Appendix I.

Analyses were made for both houses for the weeks of April 4-10, 1959, and January 30 - February 5, 1960. Since January 1, 1960, the solar house has had a solar-collector device covering the south windows on the inside, making it a semiwindowless house, admitting natural light through 30 sq ft of insulating glass in the north wall. Heat from the collector was forced downward by fans and distributed uniformly over the litter.

Experimental data collected for the two houses for the periods April 4 to 10, 1959, and January 30 to February 5, 1960 are given in Table 3.

Using the basic data contained in Fig. 1 and Table 2, calculations were made to determine the water consumption and the water output by birds. A sample calculation is shown in Appendix I. The water consumption was based on bird weight, rate of laying, feed consumption and temperature. The difference between calculated input and output of water by the birds ranged between 8 and 9 percent in favor of input (Table 4). For design purposes, it would be conservative to use the input values calculated from data in Fig. 1 and Table 2.

The calculations summarized in Table 5 for heat production by the birds were based on calorimetric data obtained by Ota (9) and given in Fig. 3. The heat derived from the lights and motors was calculated from the actual kilowatt-hours consumed. The heat losses from the building include the heat lost by ventilation and by conduction.

Referring to Table 5, it may be seen that, for the windowless house, the calculated heat output was less than the input. Equal input and output estimates should not be expected, but they should not differ more than about 10 percent. It may be that the actual U value for the building was different than the calculated U value. Also exfiltration, solar radiation effects, and line voltages affecting lights and fan operations were not determined.

The positive differences for the solar house indicate gain of solar heat. However, the 3990 Btu difference for the solar house, January 30 - February 5 test, would amount to 710 Btu per day per square foot of glass area in the south windows, which is probably higher than the amount available. The reason for this discrepancy has not been determined. Further investigations, including calibration of the houses, are necessary to evaluate the solar collector.

Table 6 compares the apparent gains of solar heat through the windows, assuming an equal number of hens in the two houses.

TABLE 4. CALCULATED WATER INPUT AND OUTPUT BY BIRDS USING BASIC DATA

	April 4 - 10, 1959 W.H.	S.H.	Jan. 30 - Feb. 5, 1960 W.H.	S.H.
Number of birds	430	406	445	456
Water total				
Input, pounds per day	278	262	266	278
Output, pounds per day	252	239	244	258
Difference, percent	9.3	8.8	8.3	7.2

TABLE 5. CALCULATIONS OF HEAT PRODUCTION AND REMOVAL

	April 4 - 10, 1959 W.H.	S.H.	Jan. 30 - Feb. 5, 1960 W.H.	S.H.
Number of birds	430	406	445	456
Input, Btu per hour				
Birds	15300	14420	15100	15500
Electric	2685	972	3105	3230
Total	17985	15392	18205	18730
Output, Btu per hour				
Ventilation	14750	15100	13100	18160
Building	1460	1430	4063	4560
Total	16210	16530	17163	22720
Output-input discrepancy	−1775	+1138*	−1042	+3990*

*Probably not all due to solar gain.

TABLE 6. APPARENT DIFFERENCE IN SOLAR HEAT GAIN OF WINDOWLESS AND SOLAR HOUSES

	April 4 - 10, 1959 Windowless	Solar	Jan. 30 - Feb. 5, 1960 Windowless	Solar
Number and weight of hens	430 - 4 lb	406 - 4 lb	445 - 3.75 lb	456 - 3.75 lb
Heat removed in ventilating air, Btu per hour	14,750	15,100	13,100	18,160
Corrections for difference in number of hens, Btu per hour		+855	+375	
Corrected heat in ventilating air, Btu per hour	14,750	15,955	13,475	18,160
Less electric heat, Btu per hour	−2,685	−970	−3,105	−3,240
Heat from hens and sun, Btu per hour	12,065	14,985	10,370	14,920
Difference in apparent solar heat gain of windowless and solar houses, Btu per hour*		2,920		4,550

*Average per hour for 24-hour day.

Summary

This paper presents the heat and moisture data on Single Comb White Leghorn and Rhode Island Red laying hens. These calorimetric data were applied in analyses of tests with the experimental windowless and solar poultry houses of the West Virginia University Agricultural Experiment Station. The calculations checked closely enough to give confidence in the value of the data for practical design purposes. Procedures for these calculations are shown in the text and Appendix I.

Appendices II, III, and IV present tabulations of functional requirements for laying hens, growing chickens and turkey production.

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APPENDIX I

Data for the performance of the windowless and solar houses at the West Virginia University Agricultural Experiment Station, Morgantown, were recorded on the hour, 24 hours each day. Dry and wet-bulb temperatures were taken with a recording potentiometer. An operations recorder measured the minutes each hour the fans operated. A timer recorded the total hours each week the fans operated. Kilowatt-hour meters recorded the electrical energy consumed by the fan motors and the lights.

The general description of the two experimental houses at the West Virginia station is as follows:

	Windowless	Solar
Wall height, ft	7.5	7.5
Floor dimensions, ft	30 x 30	30 x 30
Window areas, sq ft	0	165*
U values		
Wall†	0.22‡	0.17
Roof†	0.07	0.07

Floor – 4 in. of concrete on 6 in. of crushed rocks with no edge insulation or vapor barrier.

*135 sq ft insulated glass on the south side and 30 sq ft of insulated glass on the north side.

†Vapor barrier on warm surfaces.

‡Fill insulation settled.

Following is the detailed procedure used in analyzing each house:

TABLE 1. TEST DATA ANALYSIS FOR SOLAR HOUSE, WEST VIRGINIA UNIVERSITY AGRICULTURAL EXPERIMENT STATION

Date of test: January 30 - February 5, 1960

Data	Temperature, deg F Dry bulb	Temperature, deg F Wet bulb	Heat, Btu per lb	Moisture, grains per lb
Inside	55.5	51.6	21.3	50.5
Outside	39.3	36.7	13.8	28.0
Difference	16.2	14.9	7.5	22.5

Specific volume, cu ft per lb dry air	12.65
Litter moisture, percent d.b. (34 percent w.b.)	51.5
Fan operation, percent time on	39.3
Speed cfm, at 100 percent operation	1300.0
Lights (126 kwh per week), Btu per hr	2560.0
Fans (33 kwh per week), Btu per hr	670.0
Building conductance heat loss, Btu per hr per deg F	281.0
Birds	
White Leghorn hens (3.75 lb), number	456.0
Egg production, percent	75.0
Feed consumption, lb per day per hen (Fig. 1)	0.25
Total heat, per hen per hour (3.75 × 9.05)	34.0

I. Calculations for Water Production and Removal

A. Calculations for Water Input (birds)

1 Feed consumed (Fig. 1 at 75 percent production) 0.25 × 456 .... 114 lb per day

2 Water input (Table 2)

(a) Water to feed ratio, 1.9:1 (Table 2) 1.9 × 114 .... 216 lb per day

(b) Metabolizable, free and hygroscopic water from feed, 0.54 × 114 .... 62 lb per day

(c) Total water consumed by birds, 62+216... 278 lb per day

B. Estimated Water Output of Hens

1 Fecal water

(a) Fountain water and feed consumed, 216+114=330 lb per day.

(b) Feed plus water to feces ratio (Table 2) 2 to 1; 330/2 = 165 lb droppings per day (as voided) contained 75 percent moisture (w.b.), or 124 lb per day.

(c) 75 percent of the droppings fell in pit and was removed by the gutter cleaner 165×0.75=124 lb per day containing 93 lb of water and 31 lb dry matter. The amount of droppings falling on the litter was 165−124=41 lb which contained 31 lb of water.

2 Respired water (Table 2) 0.38×279=106 lb per day

3 Egg water

$$\frac{0.75 \times 456 \times 24 \times 0.65}{12 \times 16} = 28 \text{ lb per day.}$$

4 Total water eliminated 28+106+124=258 lb per day.

5 Difference

$$\frac{(278-258)\ 100}{278} = 7.2 \text{ percent in favor of input.}$$

6 Water removed from house by ventilation

$$\frac{24 \times 1300\ (0.393)\ 60 \times 22.5}{12.65 \times 7000} = 187 \text{ lb per day.}$$

7 Water output (actual)

(a) Ventilation .... 187 lb per day

(b) Egg water .... 28 lb per day

(c) Moisture remaining in litter (estimate based on gain in litter moisture) .... 9 lb per day

(d) Water removed by mechanical pit cleaner (three-quarters of droppings removed at 65 percent moisture content) .... 58 lb per day

Total water .... 282 lb per day

II. Heat Production and Removal

A. Input, Btu per hr

1 Birds 15500.0

2 Motors 670.0

3 Lights 2560.0

4 Total 18730.0

B. Output, Btu per hr

1 Ventilation

$$\frac{7.5 \times 1300\ (.393) \times 60}{12.65} = \text{........ } 18160.0$$

2 Building loss—16.2×281 .... 4560.0

3 Total (includes solar heat gain) 22720.0

C. Difference (IIA4 − IIB3)

Apparent heat gain from solar energy, Btu per hr..... 3990.0*

III. Calculations of Humidity:Heat Ratio

22.7/7.3=3.11 grains per Btu; that is, 3:11 grains of moisture was removed with each Btu of heat in the ventilated air.

*See discussion of Table 5.

APPENDIX II

Chicken Laying Hens

I. Floor-Managed Flocks Without Use of Utility Pit

Floor space (1)

Breed	Number of hens per pen	Floor area, sq ft per hen
Small	400 to 1,000	2¾ to 2½
Large	400 to 1,000	3¼ to 3

Feeder space

5 linear inches per hen (One 5-ft trough has 120 linear inches.)

Water fountain space

1.2 linear inches per hen (Hens drink about 9 gal per one hundred hens on a hot day. The recommendation of trough space may need to be doubled in hot weather.)

Roosts (when used)

Roosts are made of 2-in. stock rounded or beveled on the upper edges. Perches are spaced about 13 to 15 in. apart.

Breed	Roost space, inches per hen
Small	7 to 8
Large	8 to 10

Roosting pit (box design)

Length, 7 to 8 ft. Height, about 24 in.
Width, about 6 ft (when against wall).
Covered with galvanized wire cloth 1 x 2 in., mesh No. 14 gauge

Light

Light regimen of 13 to 14 hr per day have been satisfactory, including natural and artificial light.
Intensity of 0.5 to 38.0 foot-candles have shown no consistent effect on production (2, 3, 4).
Light from one 40 to 60-watt incandescent lamp per 200 sq ft of floor area is sufficient.
Effects of intermittent lighting, wave length and intensity. (See references 5 and 6).

Ventilation

1 cfm per lb live weight or higher for summer cooling of the hens. In winter, adjust thermostat so that minimum fan operation is 10 to 15 min of every hour, or to remove at least respired moisture. On warm days ventilate at maximum fan capacity.

Temperature and Humidity

Winter – Near 55 F (not below 35 F) and below 80 percent relative humidity.
Summer – Small breed, not over 90 F and 70 percent relative humidity; large breed, not over 85 F and 70 percent relative humidity.

Nest

Individual—One nest for 5 hens

Breed	Width (Dimensions of nest in inches)	Depth	Height
Small	10-12	12	12-14
Large	12-14	14	14-16

Put in 1 to 2 in. of nesting material. Perch of topmost nest (for small breed) should be about 50 in. from floor for ease in collecting eggs, and perch nearest the floor about 20 in. For heavy breed, limit nests to two tiers.

Community (colony) — One 2x4-ft nest is sufficient for about 40 hens.

Trap—Use for breeding purposes. One individual nest for 4 hens.

Litter

Add litter from time to time so that depth will be about 3 to 6 in. by the time pullets begin to lay eggs.

Litter Material	Weight per 100 sq ft of floor, lb	Depth in inches
Flax straw	62½	1
Sugar-cane bagasse	95-100	3
Peanut shell	90	3.6
Sawdust*	396	4
Shavings†	133	4
Sphagnum peat moss	221	4

*Sampled at Beltsville, air dry, contained softwood — pine, poplar, etc.
†Shavings screened with ¼-in. mesh wire cloth. Consisted mostly of pine.

Feed Room

Use data of Fig. 1 and 75 percent egg production rate for calculating feed storage space, plus 2 extra days' supply for emergency.

Material	Weight per cubic foot, lb	Space per ton, cu ft*
Grain		
Barley	40	50
Corn, shelled†	44	45
Grain sorghum or milo	41	49
Oats	28	72
Soybeans	46	44
Wheat	48	42
Mash		
Finely ground	29	69
Coarsely ground	34	59
Crumbled	34	59
Pelletized, hen size	37	54
Middlings, loose	25	80

*1 bu=2,150 cu in., or 1.24 cu ft.
†Ear corn occupies about twice as much space as shelled corn.

Egg Handling Room (1)

Approximate floor area for workroom to grade and pack eggs and for storing a few days' supply of empty egg cases and packaging material.

Number laying hens	Workroom area (square feet)
1,000	80 to 100
5,000	100 to 150
10,000	200 to 225

Egg Holding Room or Cabinet

Market eggs. Temperature 55 F and 80 to 85 percent relative humidity. In areas where dewpoint temperature is higher than 55 F, the dry-bulb temperature of the cooler may need to approach 60 F.

Hatching eggs. Temperature not lower than 55 F and about 80 to 85 percent relative humidity. Eggs should not be stored more than 7 to 10 days, including transportation time to hatchery.

Suggested sizes for egg-holding cabinets and approximate size of refrigeration unit (7), eggs marketed twice weekly:

Flock size hens	Inside floor dimensions, feet	Cases of eggs*	Basket of eggs†	Refrigeration unit, ton
2500 or less	5 x 5	16	9	⅓
3000-3600	6 x 6	24	15	½
4100-5100	7 x 7	36	18	¾
7800-9600	8 x 9	64	21	1

*Cases are stacked four high.
†Each basket assumed to contain 12 dozen eggs, but generally safer to fill two-thirds to three-fourths full.

U. S. Weight Classes for Shell Eggs

Size or weight class	Minimum net weight per dozen, oz	Minimum net weight per 30 dozen, lb
Pee wees	15	28
Small	18	34
Medium	21	39½
Large	24	45
Extra large	27	50½
Jumbo	30	56

Case of eggs — 30 dozen

Approximate outside dimensions in inches:

Paper — 13 x 13½ x 24

Wooden — 12⅛ x 13⅛ x 25⅝

II. Floor-Managed Flocks with Wooden Slatted Floor (or Roost)

Floor

Floors are usually made in 4-ft squares of hardwood slats about ½ in. thick, 1½ in. deep and spaced 1½ in. apart, weighing about 25 to 45 lb. These floors are generally placed 16 to 20 in. above dirt floor of the building. Mechanical pit cleaner may be used with this type of floor.

Hen Density

General rule 1¼ to 1½ sq ft per hen (Leghorn)

Fecal Accumulation

Based on 1 to 1¼ sq ft per hen is 1¼ in. per month (8) when pit cleaner not used.

All other requirements same as in Part I of this section.

III. Confinement Rearing of Chickens with Utility Pit — Solar and Windowless Houses (9)

Floor space, 2.0 sq ft per hen

Litter, 3 to 4 in. depth

Pit design, 6 ft wide by 12 in. deep

Light

Lights for houses with utility unit through center of house over pit having roosting, watering and feeding area—

- 8-10 f.c. at the topmost tier of roosts
- 6-8 f.c. at the second roost level
- 4-6 f.c. at the bottom roost level
- 2-4 f.c. at the floor level throughout the house

General lighting — 40-watt bulb 5 ft from walls 10 ft apart — 100 sq ft per 40-watt bulb.

Feeding area — 40-watt bulb every 4 ft over feeders or 15 sq ft per 40-watt bulb.

Nest

One nest to 5 hens.

IV. Wire-Cage Managed Flock

Individual

Size

Width — 8, 9, 10 and 12 in.

Depth — 18 in.

Height — front, 18 in. and rear, 15 in.

Length of cage from back to front tip of wire floor, 24 in.

Recommended use (10)

Breed	Width of cage
Leghorn	8 in.
Rhode Island Reds	10 in.
Leghorns (two Leghorns per cage)	12 in.

Width of service aisles

Minimum — 24 in.; Maximum — 36-40 in.

Lights (11)

Regimen 13 to 14 hours (natural and artificial). One 25-watt incandescent lamp to 8 foot section of 2-row single deck cages or about 25-watt lamp to 88 square feet.

Windbreaks

(See references of California and Hawaii Agricultural Experiment Stations (12, 13))

Cooling

Needs special attention when temperature approaches 85 F. (See reference 14 regarding evaporative cooling.)

Fly control

Needs special attention in suburban areas. (See references 10 and 15.)

Community or Colony Cages (16, 17)

Size

Wire floor space 1 sq ft per hen. Galvanized wire cloth of 1 x 2 or 1 x 4 in. welded wire mesh of 14 gauge is satisfactory for floor having a slope of 1½ to 2 in. per foot.

Width of each cage 3 ft and about 5 to 10 ft long.

Light

Same as individual cages.

Fly control

Most serious problem.

V. Floor-Managed Flocks in Subtropical and Semi-Arid Climate (See reference 18)

References (Chicken Laying Hens)

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APPENDIX III

Growing Chickens

I. Broiler – Floor-managed flock on litter

Floor space (1, 2, 3)

¾ to 1 sq ft per chick from day-old to market (in about 9 weeks)

Feeder (3)

Age of chicks, weeks	Feeder space per chick, in.	Width of feeder, in.	Depth of feeder, in.	Size of feeder
0-4	1½	–	3	chick
4-9	2½	7	4	broiler

*Chicks should not walk more than 10 ft to a feeder (2). Allow just as much space for mechanical feeder.

Waterer (2, 3)

Age of chicks, weeks	Fountain space per chick, in.
0-2*	(One 1-gal metal or glass jar fountain per 100 chicks)
2-9†	0.3 - 0.5 trough

*Transition to automatic water trough made gradually.
†Broilers should not walk more than 10 ft to a waterer.

Roost

No roosts are required.

Litter

Cover floor with at least 4 in. of litter. Good litter moisture content should be less than 30 percent on a wet basis.

Ammonia

50 ppm is the maximum that young chickens withstand (4) for a prolonged period.

Temperature and Humidity

Temperature and humidity levels for good production at various age levels are unknown.

Ventilation

Studies at Beltsville show that ventilation rate of ⅓ to 1 cfm per bird have not been harmful. Data on the removal of other noxious (besides ammonia gas) airborne materials are unknown.

Heat and Moisture

Feed Consumption and Growth

APPROXIMATE GROWTH AND FEED CONSUMPTION OF BROILERS (13)*

Age, weeks	Live weight, lb	Weekly feed consumption, lb	Cumulative feed consumption, lb
1	0.17	0.19	0.19
2	0.29	0.33	0.52
4	0.79	.55	1.49
6	1.47	1.03	3.30
8	2.23	1.24	5.61
10	2.95	1.54	8.57

*For storage space, allow for one to two days' extra supply of feed for emergency.

Water Consumption

Use water to feed ratio of approximately 2:1 for winter and about 2.5:1 in summer (6).

II. Replacement Chickens – Floor-Managed flock on Litter

Floor Space (7, 8)

Age, in weeks	Square feet
0-6	½
6-12	1
over 12	(See Appendix II)

Waterer

Same as broiler and then laying hens in Appendix II

Feeder

Same as broilers and then laying hens in Appendix II

APPROXIMATE AVERAGE WEIGHT PER CHICK AND CUMULATIVE FEED CONSUMPTION PER CHICK (13)

Age, weeks	S. C. White Leghorn females	Feed consumption*	Dual-purpose breed females	Feed consumption*
0	0.09		0.09	
2	0.22		0.24	
4	0.44	1.15	.52	1.30
6	0.90		1.06	
8	1.27	4.00	1.71	5.50
10	1.73		2.40	
12	2.14	8.00	2.93	10.50
20	3.37	18.00	4.24	22.00
24	3.85	24.00	4.67	28.00

*Cumulative pounds per bird.

Water Consumption

Use water to feed ratio of approximately 2:1 for winter and about 2.5:1 in summer (6).

Roost

When used, should be provided at 6 to 8 weeks of age. (See details in Appendix II.)

Brooding

Brooder

(a) Infrared lamps—number of chicks brooded per 250-watt infrared lamp at various room temperatures (9) *(Continued)*

AVERAGE HEAT PRODUCTION AND DATA ON GROWING CHICKENS ON LITTER AT MODERATE AMBIENT TEMPERATURE (5, 6)

Age, days	Live weight, lb per bird	Ventilation, lb per hr per bird	Temperature, deg F (db)	Relative, humidity, percent	Litter, percent (db)	Consumption Feed lb per day per bird	Consumption Water lb per day per bird	Heat Production* SH† Btu per lb live weight	Heat Production* LH Btu per lb live weight	Heat Production* TH Btu per lb live weight
33	0.92	0.93	58.8	88	50.4	0.117	0.214	12.8	10.7	23.5
41	1.33	0.96	60.9	90	58.8	0.151	0.279	10.0	9.2	19.2
54	2.05	0.95	65.3	83	66.6	0.191	0.383	7.0	9.5	16.5
63	2.46	1.32	64.6	75	66.3	0.190	0.449	6.9	8.1	15.0
72	2.90	1.32	63.7	79	64.6	0.203	0.399	7.0	7.3	14.3

24-hr average heat production including increment of heat and moisture from litter.
†SH, sensible heat; LH, latent heat; TH, total heat.

AVERAGE HEAT PRODUCTION AND DATA ON GROWING CHICKENS ON LITTER AT HIGH AMBIENT TEMPERATURE (5, 6)

Age, days	Live weight, lb per bird	Ventilation, lb per hr per bird	Temperature, deg F (db)	Relative, humidity, percent	Litter, percent (db)	Consumption Feed lb per day per bird	Consumption Water lb per day per bird	Heat Production* SH† Btu per lb live weight	Heat Production* LH Btu per lb live weight	Heat Production* TH Btu per lb live weight
10	0.21	0.68	73.5	74	17.2	0.037	0.069	6.3	13.5	19.8
20	0.45	0.67	75.6	75	27.0	0.071	0.125	7.2	11.4	18.6
32	0.92	0.91	78.1	77	29.4	0.117	0.222	8.4	11.7	20.1
47	1.58	0.95	83.3	77	33.0	0.151	0.347	6.3	10.0	16.3
66	2.52	1.38	86.5	71	35.0	0.168	0.390	3.5	8.2	11.7
75	2.92	1.25	84.6	69	31.8	0.186	0.444	4.6	8.8	13.4

*24-hr average heat production and includes increment of heat and moisture from litter.
†SH, sensible heat; LH, latent heat; TH, total heat.

Room temperature, deg F	Number of day-old chicks
85	110
75	100
65	90
55	80
45	70
35	60

(b) Hover brooder (gas, electric, oil or coal) – Maximum number under hover, 300 to 500 chicks; hover space, 7 to 8 sq in. per chick.

(c) Battery brooding (10)

Age, in weeks	Space, square inches per chick
0 - 1	7
1 - 2	10
3 - 4	20
5 - 6	40
7 - 8	50

After 6 - 8 weeks of age chickens moved to rearing cage.

Brooding Temperature

Regulated at 90 to 100 F at a point 2 in. above floor and near the outer edge of canopy for the first week. Temperature is gradually lowered about 5 F per week to room temperature.

Ambient condition of the brooding pen

60 F (11) and 40 to 73 percent relative humidity (12)

Ventilation

Estimated minimum ventilation (13)

Age of chicks, in weeks	cfm per 100 chicks
1	1.6
2 - 3	2.0
4 - 5	2.5*
6 - 7	3.0*
8 - 9	3.5*

*When ammonia is present, ventilation may need to be increased to keep fumes below 50 ppm.

III. Replacement Young Chickens on Wire Floor

(See references 12 and 13.)

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4 Scarborough, E. N. That old ammonia problem, Broiler Growing, pp. 32-34, April 1959.

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11 Krewatch, A. V. Electric brooding developments and problems, presented N. Atlantic Section, ASAE, Farmingdale, N. Y. September 2, 1953.

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APPENDIX IV
Turkey*

I. Turkey Breeding

Nest (equipped with tip-up fronts preferred)

Dimensions for large type hens – 14 in. wide, 24 in. high and 24 in. long; for small type hens, 12 x 22 x 22 in.

Number – one nest per 3 or 4 hens

Litter depth – 3 to 5 in.

Egg Storage

Temperature, 50 to 60 F

*Edited by S. J. Marsden, poultry husbandman, physiology investigations, poultry research branch, Animal Husbandry Research Division, ARS, USDA.

Relative humidity – 65 to 80 percent

Storage before hatching – 7 days†

†Allow sufficient time to reach hatchery within the 7 days.

Egg Weight

Small type – 2.50 oz per egg

Medium type – 2.95 oz per egg

Large type – 3.10 oz per egg

Feed

Average daily consumption for Broad Breasted Bronze turkeys:

Tom – 1.00 lb per day   Hen – 0.55 lb per day

Water

About 100 gal per 100 turkeys per week. Current data lacking for various breeds.

Feeder space	Linear feet per 100 birds‡
Small turkey	20
Medium turkey	23
Large turkey	25

‡4-ft feed trough feeding from both sides has 8 linear feet.

Waterer	Linear feet per 100 birds*
Small turkey	10
Medium turkey	11
Large turkey	12

*2-ft trough feeding from both sides has 4 linear feet.

Floor space, sq ft per hen	Confined to buildings	Housed and yarded
Small turkey	10	6
Medium turkey	11	7
Large turkey	12	8

Roosts

Small turkey – 12 in. of space

Medium turkey – 14 in. of space

Large turkey – 16 in. of space

Roost made of 2½-in. round poles or 2 x 3 or 2 x 4 lumber with wide side up and upper edges bevelled and nailed over wire cloth of 1 x 2 in. mesh, 12 gauge wire, or 1 x 4 in. mesh, 11 gauge wire to keep birds off the droppings.

Spacing of roosts 20 to 24 in. apart and 2 to 3 ft above floor.

Temperature and Relative Humidity

In a cold northern climate, Broad Breasted Bronze toms' fertilizing capacity improved when kept in room at 65 F five weeks prior to mating. There is some evidence hens held at constant temperature above 60 F laid smaller eggs and showed higher incidences of broodiness (1).

Lights

Average intensity of 1.7 to 2.5 foot candles at roosting height for males and females. A total of 12 to 15 hr of white light is sufficient. Turkeys respond to white or red light, but not blue. As a rule of thumb, 60-watt white incandescent lamps spaced 10 ft apart and 6½ ft above floor and roosts provide sufficient light. Morning lights are recommended when natural light is utilized. Where natural light is excluded, a light day of 12 hr at the start, gradually increased to 15 hr is suggested.

Number of Toms for Mating

	Ratio of hens to tom single-male matings	Ratio of hens to tom flock matings*
Small turkeys	20:1	14-15:1
Medium turkeys	18:1	12-13:1
Large turkeys	16:1	10-11:1

*In flock matings, some breeders prefer to divide the suggested numbers of toms into two groups, then alternate the two groups every 3 to 7 days.

Heat and Moisture Production

Data lacking

Ventilation

Research data lacking; practical information given by Nabben (2).

II. Growing Turkeys

Brooder House Management (General practice for floor-managed flocks)

(a) Number per pen – 300 poults preferred maximum through 8 weeks of age.

(b) Floor space without sunporch – 1½ sq ft per poult through 8 weeks of age; 2 sq ft to 12 weeks; and 2½ sq ft to 16 weeks. With yard or sunporch – about half the recommended space in the house.

(c) Temperature and humidity* — 0 through 6 weeks of age, 95 to 100 deg under hover; 70 to 75 deg on floor away from hover. When floor temperature falls below these recommendations, raise hover temperature 5 F. Desirable to maintain 70-75 percent relative humidity.

*Data lacking on the performance of poults at various humidity levels and on "comfort zone" for various ages of poults.

(d) Ventilation — Data lacking — satisfactory results may be obtained by keeping ammonia concentration in the air below 40 ppm and maximum ventilation rate of about 1 cfm per pound weight for summer (same as chickens).

(e) Light — Natural daylight or 13 to 14 hr of artificial light with an intensity of 1.7 to 2.5 footcandles at floor and roost level is sufficient. Data lacking.

(f) Roosts — Optional but desirable. Provide about 3 in. of roost space per poult up to 8 weeks of age.

(g) Litter — For the first week or two, use only sand, non-splinty planer shavings, peat moss, chopped screened corncobs, or vermiculite. If other types are used, cover with sacking for the first 10 days. Start with 2 in. of litter and stir and add litter as needed. Slat floors made of plaster laths ¾-in. apart are preferred to litter during the brooding period. The effect of litter moisture on the performance of poults is lacking — presumably litter moisture content up to 30 percent wet basis may be satisfactory (same as chickens).

(h) Feeding and Watering Space (3) —

Age, weeks	Feeder minimum, ft per 100 poults*	Waterer minimum, ft per 100 poults	or	2 fountains
0-8	16	3		1 to 2 gal cap.
9-24	20	3.5		———

*Linear feet equals one foot of feeding or watering space, or one 4-ft trough equals 8 linear feet.

(i) Current feed and water-consumption data are lacking for various breeds of turkeys. (See reference 4 for approximate data.)

Brooding

Hover

(a) Space under hover — minimum 10 to 14 sq in. per poult. Maximum number per hover, 300 poults.

(b) Temperature at the edge of hover and 3 in. above floor (litter) 95 F at the start. Decrease temperature 5 F per week to 6 weeks of age, considering the behavior of poults at all times.

(c) Light — Night lights of 5 to 7½ watts of white incandescent bulb under the hover are desirable.

(d) Confinement wall or ring around hover — Winter, use corrugated paper 12 in. high or other similar solid material to confine poults near hover — about 2 to 3 ft from hover to 7 days of age and then removed. In summer use wire mesh screens to permit air circulation.

Battery

(a) Length of time used, 14 to 17 days

(b) Space, 25 sq in. per poult

(c) Temperature management under heating unit, same as hover system

(d) Lights, same as hover system

Heat and Moisture Production

No data available

Weight Standards for Growing Turkeys (4)

Age, weeks	Broad Breasted Bronze Male	Broad Breasted Bronze Female	White Holland Male	White Holland Female	Beltsville Small White Male	Beltsville Small White Female
	pounds		pounds		pounds	
1 day	0.134	0.134	0.120	0.120	0.115	0.115
4	1.27	1.12	1.01	0.86	0.96	0.83
8*	4.26	3.57	3.50	2.76	3.25	2.50
12	8.78	6.98	6.75	5.30	6.10	4.50
16†	14.08	10.34	10.23	7.65	9.10	6.35
20	18.60	13.00	13.75	9.60	12.10	7.95
24‡	23.10	14.90	17.20	11.20	15.10	9.35
28	26.80	16.35	20.30	12.40	18.10	10.55
32	29.75	17.45	23.20	13.45	20.20	11.30
36§	32.00	18.50	25.00	14.10	21.40	11.70

*End of normal brooding period.
†Fryer-roaster age for Beltsville white turkeys.
‡Roaster age for all breeds.
§Age at which standard weight normally is attained.

References (Turkey)

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2 Nabben, M. The ABC's of turkey house ventilation, *Turkey World*, 35(3):10-31. March 1960.

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Design Analysis for Poultry-House Ventilation

Merle L. Esmay

Member ASAE

IN proposed new poultry houses or existing old ones, two questions arise: *(a)* How much ventilation air exchange is possible, and *(b)* how much water will this air remove? If no supplemental heat is to be added, the amount of air exchange possible is based upon the difference between the heat lost from the house by conduction and heat produced by the birds.

The approach to the analysis in this paper is based upon the unit of floor area of one square foot.

What Size and Shape of House?

The first consideration is the effect of the size and shape of the house on conduction losses. Fig. 1 shows graphically the exposed surface area of single-storied houses with horizontal ceilings, in square feet per square foot of floor area. As an example, it may be determined from this graph that a 36 x 100-ft house has 1.60 sq ft of exposed wall and ceiling area for each square foot of floor area. In comparison, a 72 x 100 ft house has 1.38 square feet of exposed surface area. This is a saving of approximately 14 percent in exposed surfaces for each unit of floor area.

How Much Insulation?

The second consideration is how much insulation does the house have or should it have if it is to be constructed new or remodeled. This analysis is based upon the average calculated heat transfer coefficient for all exposed wall and ceiling area for the house expressed as *Uav* (Btu per hour — square foot — degree F). Fig. 2 presents

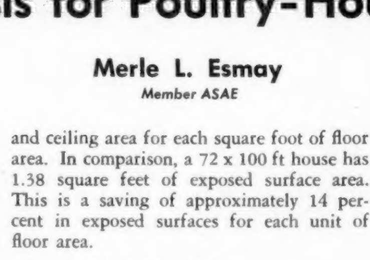

Fig. 1 Exposed surface area in square feet per square feet of floor area for houses with 8-ft ceilings

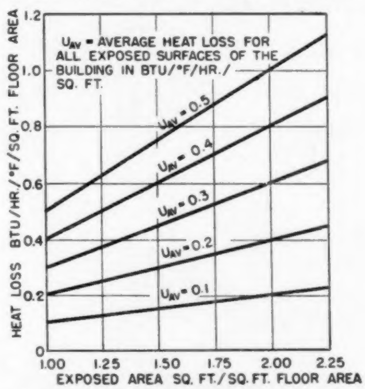

Fig. 2 Heat loss per square feet of floor per degree F temperature difference with various amounts of ventilation

The author — MERLE L. ESMAY — is professor of agricultural engineering, Michigan State University, East Lansing. Authorized for publication as Journal Paper No. 2669 of the Michigan Agricultural Experiment Station.

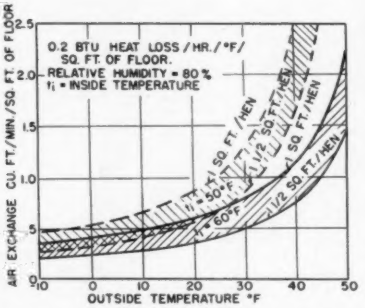

Fig. 3 Possible ventilation rates under varying drying conditions of outside and inside temperature and density of birds housed

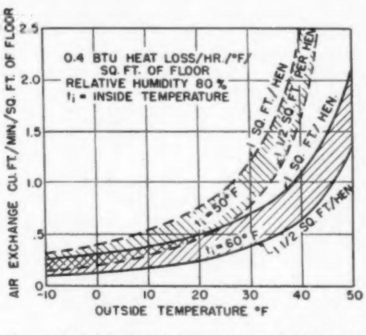

Fig. 4 Possible ventilation rates under varying conditions of outside and inside temperatures and density of birds housed

graphically the relation between exposed surface area, amount of insulation and heat loss. The house size and shape value (exposed area in square feet per square foot of floor area) as determined from Fig. 1 is entered at the base of Fig. 2. Based on insulation, existing or proposed, the heat loss value in Btu per hour per degree F per square foot of floor area may be calculated from the handbook, "Insulation Values of Construction Materials."

Continuing the previous example, the 36 x 100-ft house with a 1.60 exposure ratio will have a heat loss coefficient of 0.24 Btu per hour per degree F per square foot of floor area if the *Uav* for the building is assumed to be 0.15 Btu per hour per square foot per degree F. Comparatively, a house twice as wide would have a heat loss coefficient of 0.21 Btu per hour per degree F per square foot.

Possible Ventilation Rate

Having determined the heat loss coefficient in Btu per hour per degree F per square foot of floor area for a specific building, the calculation of possible ventilation air exchange may be made. The amount of air exchange possible is based on heat available in the house for warming incoming cold ventilation air. Laying hens weighing five pounds each are assumed to produce 55 Btu of total heat per hour (1)* The total amount of heat available is affected greatly by two management factors. One is the density at which the birds are housed, and the other is the temperature at which the house environment is maintained. Once having established these management criteria, there is a fixed relationship between outside temperature and possible ventilation air exchange. This relationship is shown graphically by Figs. 3 and 4. The possible ventilation air exchange includes the air removed by fans and by exfiltration.

To complete the ventilation system analysis, an outside design temperature needs to be selected. It is suggested that the mean temperature for the coldest winter month, in the area where the house is to be constructed, be used as the outside design temperature. For example, assume 20 F for the northern climatic zone.

Following the previous example for the poultry house with a 0.24 Btu per hour per degree F per square foot floor area heat loss coefficient, the possible ventilation air exchange may be determined from Figs. 3 and 4. Assume the management decisions made on this house were as follows: (1) birds to be housed at 1¼ sq ft per bird, and (2) inside environmental temperature of 55 F.

All of these variables cannot easily and simply be shown on one graph. Due to the specific criteria of this example problem, some interpolation will be necessary between Figs. 3 and 4. Fig. 3 is for one heat loss coefficient of 0.2 and Fig. 4 is for the heat loss coefficient 0.4. The coefficient for this example problem of a 36 x 100-ft house is 0.24 Btu per hour per deg F per square foot of floor area.

First from Fig. 3 with a 0.2 heat loss coefficient the ventilation air potential for 20 F outside temperature, 55 F inside temperature and bird density of 1¼ sq ft per bird is 0.63 cfm per sq ft of floor area according to the straight line interpolation between 0.75 for $t_i = 50$ F and 0.50 for $t_i = 60$ F. From Fig. 4 with a 0.4 heat loss coefficient, the potential air capacity is 0.50 cfm. Interpolating between the two graphs for the example heat loss coefficient of 0.24 in the following way gives a potential ventilation air exchange of 0.60 cfm per sq ft of floor area.

Example of interpolation calculation:

$$0.63 - \left[\frac{(0.24-0.20)}{(0.40-0.20)} \times (0.63-0.50)\right]$$
$$= 0.63 - (0.2 \times 0.13)$$
$$= 0.63 - 0.026 = 0.604 \text{ cfm per sq ft of floor area.}$$

For the 72-ft wide house the ventilation air exchange would be 0.62 cfm per sq ft of floor area.

Moisture Removal By Ventilation

The final question is: How much moisture will the ventilation air remove from the house? Figs. 5 and 6 show graphically the amount of moisture removed. For example, with 20 F outside design temperature, 55 F inside temperature, and a density of 1¼ sq ft per bird, the moisture removal for the 36 x 100-ft house is found to be 0.35 lb per day per square foot of floor area. For the 72-ft wide house, the moisture removal potential would be 0.36 lb per day per square foot of floor area. This is only slightly better.

Total moisture production of laying hens as determined by Ota, Garver and Ashby (1) is approximately ⅔ lb per day. Where layers are housed at 1¼ sq ft per bird, this would be a moisture production equivalent of 0.53 lb per square foot of floor area. It will immediately be observed from Figs. 5 and 6 that the ventilation system cannot be expected to remove all of the moisture when outside temperatures fall below the assumed mean temperature of 20 F. Much of the moisture is, of course, in the droppings and removal of them regularly will be required in most cases to maintain an optimum environment in so far as dampness and litter conditions are concerned.

Discussion

The accuracy of this analysis depends upon the accuracy of the calculation of the average heat loss value *(Uav)* and the assumption of 80 percent relative humidity conditions inside and outside of the house. This analysis was made using the total enthalpy method of determining the amount of air and moisture exchange. Similar

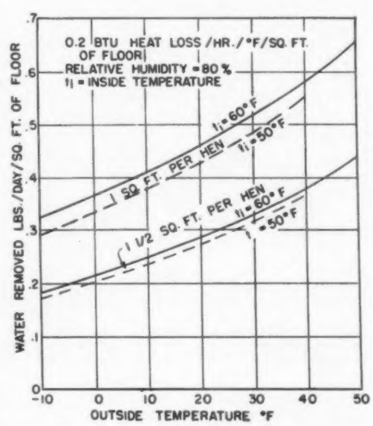

Fig. 5 Moisture removal by the maximum potential ventilation with various conditions of outside and inside temperature and density of birds housed

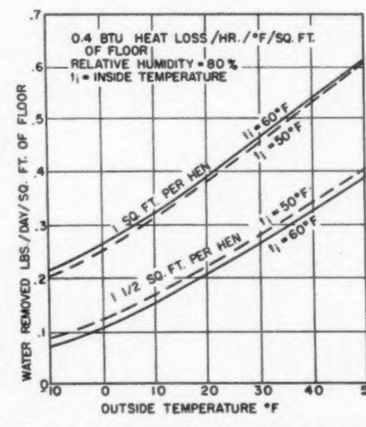

Fig. 6 Moisture removal by the maximum potential ventilation with various conditions of outside and inside temperatures and density of birds housed

*Numbers in parentheses refer to appended references.

graphs could be developed for layers weighing other than five pounds each and for the equivalent heat production values as presented in the article entitled, "Heat and Moisture Design Data for Poultry Laying Houses"(2).

The design criteria for the dimensions, insulation and ventilation of poultry laying houses for the northern two zones of the United States must be based upon the air and moisture exchange necessary for the specific house. The graphical analyses presented in this paper show the relationships of house size and shape, insulation, inside and outside temperatures and bird density to the possible air, heat, and moisture removal from the house.

An actual ventilation air exchange capacity of 3 cfm per sq ft of floor area should be provided for poultry laying houses in the northern zones of the United States. This maximum capacity is needed mainly during the warmer seasons of the year. To provide this air exchange, fans must be rated to deliver the specified quantity of air for the house against a ⅛-in. static pressure difference.

A practical, economical and effective ventilation system is the exhaust type. Exhaust fans are located in the sidewall and air is brought into the house from the attic through long narrow crack inlets. For houses up to 40 ft wide, the exhaust fans are located in one wall and the continuous crack inlet (1 to 1½ in. wide) is located in the ceiling along the opposite wall from the fans. This provides a simple cross flow movement of air. For wider houses a workable system becomes more complicated as air must be brought in through center cracks in the ceiling of the house and exhausted to both sidewalls.

Positive ventilation of all parts of a poultry house is best obtained when all fans operate at the same time. One thermostat will provide this control for the complete house. In the northern zone of the United States a single thermostatic control may allow the fans to be turned off for undesirably long periods. Information derived from Figs. 4 and 5 will indicate what proportion of the time the fans will operate during low outside temperature conditions.

A two-step thermostat may be used to provide more continuous operation of part of the fans. Every third fan may be connected to the lower setting of the thermostat and the rest to the higher setting. The lower setting may be adjusted five degrees or so below the other and at the very minimum temperature desired in the house. This would provide a more nearly continuous 1 cfm of air exchange throughout the house at much lower outside temperature conditions.

References

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2 Longhouse, Ota and Ashby, Heat and moisture design data for poultry laying houses, AGRICULTURAL ENGINEERING, vol. 41, no. 9, Sept. 1960.

Housing Design and Equipment for Economical Broiler, Egg Production

Frederick P. Stephan
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THE increase in competition among broiler raisers and egg producers, with lower prices for their produce as the normal result, has made it imperative to reduce production costs in every possible area. The average size of these operations has been rapidly increasing for, to be economical, an operation should be large enough to buy basic supplies at a low price; use labor, buildings and equipment efficiently, and provide sufficient dollar return to the operator. While the size is frequently limited by the amount of capital available to each enterprise, careful consideration should also be given to the marketing potential for the product and to the availability of management talent to avoid the establishment of an operation that could be too large and consequently unstable. When the size of operation has been determined, selection of building construction and layout, as well as type of equipment and arrangement, must be made by analyzing the relative potential returns for available combinations.

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Housing Design

Providing housing that is functional yet low in cost is the greatest challenge before farm-building designers today. This challenge can be met through shrewd use of materials, both old and new, such as: plastic sheets and films; adhesives; preformed sheets of aluminum or steel; chemically treated wood, hardboard and fiberboard; low and standard density concrete, and glass. Costs can be cut by having materials perform more than one function, such as having prefinished covering materials carry some of the structural load. Where possible, use should be made of covering materials that will provide insulation value, or a vapor barrier, or a surface finish that will eliminate painting. While looks may be important selling tools, they must not be bought at the expense of an uneconomical operation. A neat combination of inexpensive materials that might show weathering, but would remain functional within the planned life of the building, could provide more return than the costly, fancy job and yet remain within the limits of aesthetic acceptability.

The framing design should be checked carefully for possible reduction of material through better distribution of loads. Use should be made of lighter materials to cut dead loads; increase allowable stresses or decrease design snow loads to values commensurate with risk where building codes are not restrictive. The rebirth of the pole-type building has come as a result of this basic need for functional housing at minimum cost.

Further departure from conventionality may be required as competition increases; for example, the round building requires the minimum enclosure surface area but framing that shape has been uneconomical. Geodesic and pneumatic structures have removed this objection.

Equipment Selection

The value of equipment may be divided into two areas; function and labor saving. Taking the automatic poultry feeder as an example, the function would be temporary storage of feed in the hopper and the support of feed in position for the birds to eat it. The labor-saving would be found in the automatic distribution of feed to the birds. The cost of each of these values must be compared with alternate means for accomplishing the same function and with the value of the labor saved.

Further value may be obtained through proper arrangement of equipment in the house. Flow of materials should be direct to the point of use or removal. Equipment arrangement must allow free movement of caretakers to minimize cost of remaining labor and yet permit handy access for birds to maintain high production efficiency. Examples and suggestions are given in the remainder of the discussion.

Brooding Chicks

Broiler growing begins when the chicks are delivered to the farm and are placed under the brooders. The brooders, whether central system or unit type, should be designed and arranged to permit easy inspection of the chicks while doing an efficient job of maintaining chick comfort. Brooders should be arranged to be tilted up or hoisted up out of the way when taking out finished birds and cleaning out the house.

The efficient broiler grower is intent on raising a thrifty bird to market weight as rapidly as possible. In the process, he must distribute tons of feed, water and fresh air to his birds daily.

Feeding

Feed will be delivered to the farm in bulk loads of approximately 10 tons. Roads and lanes must be adequate to take these loads at all times of the year. Most bulk trucks are equipped to unload mechanically or pneumatically into bulk storage bins. The bins should be located at the points of feed use permitting their unloading augers to discharge directly into an automatic feeder hopper or a filling cart for hanging feeders. The cost of feed is the largest component of the total cost of operation; equipment must be designed and arranged to minimize the opportunity for loss or spoilage.

Watering

The water supply should be reliable and fit for human consumption. Piping must be

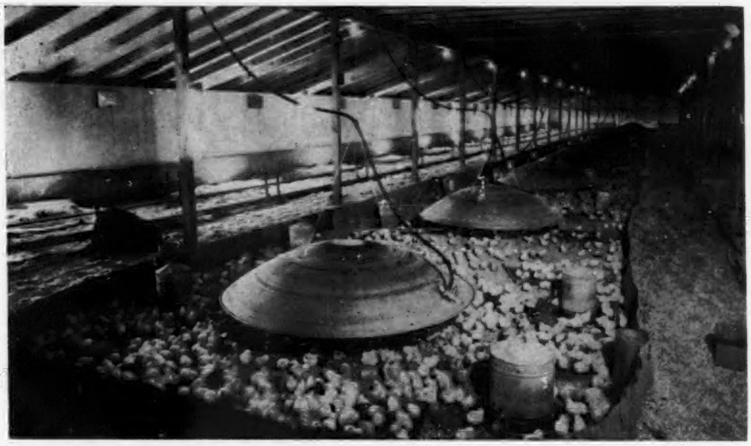

Fig. 1 A typical housing and equipment arrangement for producing 6500 broilers. Brooders that may be hoisted out of the way are located in the central area with two lines of automatic feeders along each side. While only one line of water trough is shown being installed at the right, a second line at the left would increase the availability of water. Large doors at each end permit tractor cleaning. Ventilation intakes are located on the sidewalls and exhaust fans are at the peak of the roof with thermostats on columns

large enough to avoid limiting flow below maximum requirements in hot weather. The water supply to each flock should be filtered to remove sand and scale and then be metered to determine daily consumption. Fittings for a medication proportioner should be provided downstream from the meter. All piping should be protected from freezing temperatures in winter. Waterers should have a shape and finish that expedites cleaning. Drains should be provided to take away overflow water when cleaning waterers.

Lighting should be distributed over feeding and watering areas. It should be controlled by time clock to eliminate neglect or drudgery of manual operation.

Ventilation

Proper ventilation must supply oxygen, and also dilute and remove carbon dioxide, ammonia, disease organisms and water vapor without causing drafts or producing an excessively low air temperature within the room.

Limited by the body heat production of the birds and a controlled room-air temperature, the ventilation rate must fluctuate with changes in body heat output, solar radiation, and outside air temperature. The amount of fluctuation is less in a well-insulated house than it is in a poorly insulated one; however, during cold weather (below 20 F), the ventilation rate will drop below that required to remove the moisture given off by the birds. When this situation occurs, there will be a build-up of moisture, usually in the litter, and possibly as condensation on some building surfaces. The system for moving ventilation air should have sufficient extra capacity to produce a drying condition during warmer weather that will remove this moisture before its accumulation becomes excessive. If ambient temperature conditions which prohibit this storage and recovery operation prevail, the most economical supplemental heat available should be used to permit an average ventilation rate that will control moisture.

Most ventilation systems use electric fans located in the air outlets to provide a forced exhaust. The make-up air is drawn into the room through uniformly distributed sidewall openings or through distribution ducts. Cold, fresh air should be tempered by mixing with warmer air in the room before coming in contact with the birds. The ventilation fans should be controlled by thermostats located in the room where they will not be directly affected by incoming cold air.

Handling Birds and Removing Litter

When arranging equipment in a broiler house, it is important to consider the two most laborious jobs: loading out the finished birds and cleaning out the litter. With brooders and waterers raised to the ceiling and the automatic feeder troughs raised or moved out of the way, the job of catching and crating the birds is simplified. The trucks may be driven inside the building if there is sufficient ceiling height; if not, doors should be located around the building to decrease the distance the birds must be carried. A lifting device or elevating conveyor should be used to help stack the crates on the truck.

With the birds gone, a tractor with scraper and loader can be used to clean out the old litter. New litter should be placed with a self-unloading wagon.

Manure Removal for Laying Hens

Equipment requirements for feeding, watering, lighting and ventilating laying hens will be similar to those already described for broilers. However, laying hens being confined for a longer period and being practically full grown during the entire period of housing, special attention should be paid to the problem of manure removal.

The manure from caged layers is deposited in rows which may be mechanically removed with scrapers or conveyers. Layers housed on the floor are usually fed, watered and provided with roosts located over some form of droppings pit. The droppings, a large percentage of which are voided during activity around this equipment, may be periodically removed from the house by a conveying mechanism. This practice reduces the moisture load on the ventilation system and minimizes labor required when cleaning the house.

In recent years, the floor area covered by droppings pits has varied from 25 to 100 percent. The remaining floor area has been covered with an absorbent litter material which the birds use to dust themselves in. This litter is left in place for one or more years. When it is removed, it is usually pushed into the nearest droppings pit where it is taken out by the manure-removal system.

Handling Eggs

To protect the investment in good birds and feed, considerable attention should be

Fig. 2 A laying house equipped with tiered roosting, feeding and watering over a droppings pit containing a mechanical cleaner. Eggs roll out the rear of the nests located to back on the aisle, through which egg collection baskets are carried on a track. Ventilation intake ducts extend from the sidewall. Exhaust outlets are in the ceiling over the track. The birds have feed, water, litter, nests, and roosts within 10 feet

given to collecting and preserving the quality of every egg that is laid. Hens prefer to lay their eggs in a soft, cup-shaped nest that affords them some privacy and protection from attack. The conventional straw nest satisfied this urge; however, as more hens tried or were required to use the same nest, the chance for egg breakage and soilage increased. Eggs had to be collected frequently to avoid this situation.

The rollaway-type nest was developed to reduce egg collection labor and to keep eggs cleaner and cooler by having them roll out into a collection tray. Because the nest bottoms have been hard, flat, sloping affairs, the hens have to be trained to lay in them by operating them at first as conventional, straw nests.

Eggs collected by hand from these nests are placed in baskets that may be carried on carts or on carriers hung from overhead tracks. The baskets are taken to the egg room for processing. Efforts are being made to reduce egg collection labor by adding simple belt conveyors to rollaway nests that deliver the eggs to the egg room for processing. The most successful commercial models use a specially shaped nest bottom which is attractive to the hen yet allows the egg to roll out onto the conveyor belt.

No matter how careful the operation, many of the eggs will have dirt spots that must be removed to make them commercially acceptable. These spots may be removed by hand with sandpaper; however, large numbers of dirty eggs in the bigger operations have encouraged the development of egg-washing machines that, when operated properly, can produce a clean egg without damaging the interior quality. A light oil is frequently sprayed over the cleaned eggs to seal the pores in the shell thereby helping to maintain quality and increase storage life.

Cleaned eggs must be candled, graded and packed at the farm or cased and sent to a grading station. Automatic, on-farm grading equipment is available but candling and packing must be done by hand. The complete mechanization of egg handling from hen-to-retail package will be the next advancement in egg production.

Conclusion

The foregoing discussion and examples are intended to guide the planner in analyzing his particular poultry-housing problem. After determining the value of available components, he must check the practical combinations against possible production improvement and labor saving to determine which will be most economical.

While the mechanization of what used to to be called "chores" has greatly increased the number of birds each poultryman has capacity to care for, it is very important that he should not erroneously regard this release from manual labor as an invitation to sit on the porch and watch the money roll in. Instead, he should take this as an opportunity to spend more time maintaining health and efficiency in his operation and developing the most lucrative market for his produce.

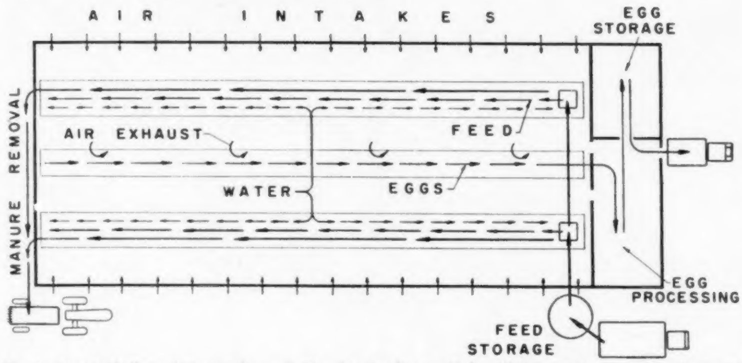

Fig. 3 Materials-flow diagram for a laying house, from which will be noted the direct flow and handy access for birds

Poultry Houses and Equipment for the South

L. N. Drury and **D. O. Baxter**
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THE best poultry house is one which tends to maximize net returns to the operator. This does not necessarily mean stress-free housing, but rather housing which with practical levels of breeding, feeding, and management will produce high-quality eggs and meat at the lowest unit costs.

Optimum environmental conditions for chickens have been partially demonstrated under laboratory conditions, but the effects of interactions of light, temperature, humidity, air movement, radiant heat, and duration of exposure are not well known. Results of research under controlled conditions suggest that egg production, growth, and feed efficiency will improve as the inside air temperature approaches the optimum, but furnishing the optimum conditions has not been economical in other experiments. Hutchinson and Sykes (10)* reported that hens acclimatized by increasing exposure to heat withstood ambient temperatures 5F higher than their unacclimatized sisters. Yeates *et al* (23) reported that light-breed layers can tolerate air temperatures 5F higher than heavy-breed layers. Bottorf (1) suggested that large fluctuations in ambient temperature trigger the onset of certain diseases in broilers, but Squibb (21) reported that wide diurnal variations in ambient temperature did not adversely affect egg production.

The effects of floor-space allowance, litter condition, temperature, air quality, and air movement on the incidence and severity of poultry diseases has received only minor attention in research.

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*Numbers in parentheses refer to the appended references.

Floor Space

The general floor space recommendations for southern conditions are 3.0 sq ft per light-breed hen and 1.0 sq ft per broiler. With these space allowances, the summer heat production by broilers is approximately 3.2 times as much per square foot as that by layers, and the winter moisture production approximately 4.5 times as much by broilers as by layers. These estimates support the belief that control of heat and moisture is more important in broiler houses than in laying houses.

Driggers (2) has shown that light-breed hens will lay at a satisfactory rate with as little floor space as 1.5 sq ft per hen if adequate feeder and waterer space is provided, but decreased floor space allowances in gravity-ventilated houses without pit cleaners resulted in wet litter, dirtier eggs, and increased cannibalism. An economic analysis by Judge *et al* (12) showed that a floor space allowance of 0.5 sq ft per broiler would give greater net returns than larger space allowances, even though growth rates were reduced when the smaller spaces were used. It may be surmised that proper control of temperature and ventilation, and provision for adequate feeder, waterer, roost, and nest spaces would reduce the floor space requirement. Cannibalism can be reduced by debeaking the birds.

Current House Designs

A survey of currently recommended poultry-house designs for seven southern states is summarized in Table 1. None of the designs include mechanical ventilation, and only one includes insulation; but most of them provide large openings for gravity ventilation in winter and straight-through ventilation in summer. The 30-ft (width) houses are most commonly recommended for broilers and the 40-ft houses for layers, based on the assumptions that more ventilation is required for broilers and that gravity ventilation works better in narrow houses.

TABLE 1. SUMMARY OF CERTAIN FEATURES OF POULTRY HOUSE PLANS FOR SEVEN SOUTHERN STATES[1]

	House width, ft	Sidewall height, ft	Sidewall opening height, ft[2]	Percent sidewall ventilation area per floor area[3]	Ridge opening height, in.[2]	Percent ridge ventilation area per floor area[3]	Roof slope, in./ft	Roof overhang, ft
Range	24 - 40	6.0 - 8.8	1.9 - 5.0	9.1 - 37.5	4 - 12	2.2 - 8.3	3 - 5	1 - 3
Average	32.9	7.35	4.1	25.7	8.2	4.24	4.1	2.1
Most common	30 & 40	7.0	4.5	26 & 30	6.0	5.0	4	2.5

[1]Current broiler house and layer house plans of land-grant colleges in Alabama, Arkansas, Georgia, Louisiana, North Carolina, Texas, and Virginia.
[2]Gross vertical dimension of opening on one side, adjusted to equivalent height for opening extending full length of house.
[3]Gross area for both sides. All ridge ventilators are continuous for the full length of the house.

Most laying houses in the Southwest, and many in the Southeast, do not have shutters on the sidewalls during summer; but curtains or other closures are usually used on the north sides during winter. Allowing the sidewall openings to extend to the floor level in summer helps to maintain more air movement over the birds. In addition to the plans of land-grant colleges and the USDA, several commercial organizations are offering poultry-house designs adapted to their products, and some manufacturers are offering prefabricated houses.

VENTILATION, INSULATION AND HEATING

Ventilation is necessary to provide the desired air quality and to remove moisture from the litter or droppings or both. The greater the difference between inside and outside temperatures, the greater the moisture-absorbing capacity of the ventilating air.

An analysis by Liu *et al* (13) indicated that insulation would not be economical for winter egg production in most of the South. This analysis was based on a heat production of 55 Btu per hr for a 5.0-lb hen and on estimated losses in egg production and feed efficiency due to deviations from optimum temperature (55 to 60 F). No similar analyses are available for summer egg production, nor for broiler houses in the South for any season.

Since the optimum temperatures for broilers average higher than those for egg production, one can surmise that insulation would be more economical for broiler houses than for laying houses. Prince (17) found a linear relationship between ambient temperature and feed efficiency of broilers and he concluded that supplemental heat to maintain a temperature of 55 F would be economical in insulated broiler houses in Connecticut. The ventilation rate may also affect the incidence and severity of respiratory diseases in chickens; but the relationships have not been fully found (12-a).

Ventilation Rates for Layers

The lowest ventilation rate which will maintain satisfactory conditions in the house will cost least to provide and will permit the highest inside temperatures. Over a period of several weeks the moisture removal must equal the moisture production, but litter can absorb fecal moisture during cold, wet periods and release it during warm, dry periods. Thus the ventilation rate during cold, wet periods need only be sufficient to remove the moisture respired by the birds.

Data on moisture and heat output of both laying hens and broilers are given by Longhouse and Ota (14). Methods of calculating moisture and heat balances for the design of ventilation systems are given in the same paper. The selection and control of fans and location of fans and air inlets have been discussed in detail in previous publications, and need not be repeated here. It should be noted, however, that approximately 2.5 air changes per hour may result from infiltration even when the fans are not operating.

Insulation

When the maximum winter ventilation rate has been found, the minimum insulation which will maintain the desired temperature differential may be calculated, using the equation

$$Q_s = (t_i - t_o)(AU + VC)$$

in which Q_s = sensible heat, Btu per hr; t_i = inside temperature, deg F; t_o = outside temperature, deg F; A = total exposed area of house, sq ft; U = over-all heat transfer coefficient in Btu per hr per sq ft per deg F; V = air flow, lb per hr, and C = specific heat of air, Btu per lb air per deg F.

The example below illustrates a method of calculating the U value for the house, when the following assumptions are made: The house is 40 by 150 ft with 7-ft sidewalls; the roof area for heat transfer is 1.06 times floor area (gable roof, no ceiling, slope 4 in. per ft) with a U value of 0.31; the window area is 0.05 times floor area with a U value of 1.23. It is further assumed that the heat available to offset the conduction heat loss (AU) is 4,400 Btu per hr per deg F temperature difference. The amount of available heat for any situation may be calculated using the data and methods presented by Longhouse and Ota (14).

Roof

$AU = (40 \times 150 \times 1.06)$ sq ft $\times$ 0.31 Btu per hr per sq ft per deg F = 1,970 Btu per hr per deg F

Window

$AU = (40 \times 150 \times 0.05)$ sq ft $\times$ 1.23 Btu per hr per sq ft per deg F = 370 Btu per hr per deg F

Wall

$AU = (4{,}400 - 1970 - 370) = 2{,}060$ Btu per hr per deg F

Allowable wall

$U = 2{,}060$ Btu per hr per deg F/2,630 sq ft (net wall area) = 0.78 Btu per hr per sq ft per deg F

A wall of ¾ in. drop siding ($U = 0.58$) may be used, and the equation $U(t_i - t_o) = f_i(t_i - t_1)$ can be used to check whether condensation will occur, f_i is the inside film coefficient, 1.9 and t_1 is the inside surface temperature. For 35 F outside, the inside surface temperature is found to be 42 F. Since the dewpoint of the inside air is 39 F (45 F, 80% RH), there will be no condensation on the wall. There will, however, be some condensation on windows whenever these conditions exist. Since the over-all U value used is lower than that required by the design, a higher ventilation rate or a greater temperature rise could be used.

Ventilation Rates for Broilers

Winter ventilation requirements for broiler houses may be calculated by similar procedures. The appropriate values for heat and moisture production of broilers should be used. Also, it may be economical to provide higher inside temperatures for broilers. This can be done by applying more insulation.

Hot Weather Ventilation

In hot weather the ventilation problem is one of removing heat in an attempt to keep the inside temperature nearly as low as the outside temperature. The equation $V = Q_s/C(t_i - t_o)$ can be used to find the air flow required for any assumed temperature differential if Q_s is known. Q_s can be estimated as follows: Sensible heat production of hens at 90 F ambient = 6.4 Btu per hr per lb weight $\times$ 0.40 sensible heat factor $\times$ 4.5 lb per hen (adult) $\times$ 4,000 hens = 46,000 Btu per hr; solar and litter heat = 65 percent of 46,000 = 29,900 Btu per hr (17-a); thus total heat to be removed = 75,900 Btu per hr. Heat flow through the house (assuming 9,290 sq ft exposed area and an over-all U value of 0.485 as in the example on insulation, and a 2 F temperature differential) = 9,290 $\times$ 0.485 $\times$ 2 = 8,800 Btu per hr. The remainder, 67,100 Btu per hr, must be removed by ventilation. Thus

$V = 67{,}100$ Btu per hour/0.2375 Btu per lb air per deg F $\times$ (92-90 F) = 141,000 lb air per hour, or 32.5 air changes per hour

It is doubtful that a power ventilation system of this capacity would be economical, in view of the possibility of letting natural ventilation do the job. For example, a 1-mph wind† at right angles to the 40-ft house, (assuming ½ of this velocity inside if sidewalls are open) will give 44 fpm $\times$ 60 min per hr/40 ft per air change = 66 air changes per hr. This is twice the required rate.

COOLING

In most of the South there are as many or more hours with temperatures above 60 deg ("optimum") as there are below.

Drury (3) reported that neither exhaust fans, foggers, nor evaporative coolers affected the rate of lay or mortality of White Leghorns in Georgia. Hobgood and Jaska (9) reported that evaporative cooling in Texas (pad and fan) was economical for heavy-breed layers, but was of questionable value for light-breed hens. They further reported that either foggers, pad and fan, or conventional evaporative coolers would prevent mortality due to hot weather. Drury (unpublished data) used foggers for heavy-breed layers during three consecutive summers in northwest Georgia with consistently

†Average wind velocity during summer months at Athens, Ga., is 8 mph.

improved egg production and decreased mortality.

Drury (3) reported that broilers in evaporatively cooled pens gained 0.1 lb per bird more than those in check pens, but the added electricity and feed costs exceeded the value of the extra weight gained. There was no difference in feed conversion. Heywang (8) reported similar results in Arizona.

Ventilation alone cannot reduce the inside air temperature below the outside air temperature. Measurements of air temperature and humidity in wire-walled chicken houses during the hot part of the day have shown that inside air temperatures are from 0.4 to 2.0 F higher than outdoor air temperatures and inside relative humidities are within 0.5 percent of outside relative humidities (3). Since the outdoor temperature occasionally rises above 100 F (approximate point of heat prostration for broilers and heavy-breed hens), there is justification for providing some artificial cooling as a means of preventing heat prostration of layers and broilers during heat waves. A simple and effective method of cooling poultry in wire-walled houses is the use of foggers. A typical installation consists of one 2-gph fog nozzle for each 70 sq ft, mounted 7 ft above the litter. A timer and a thermostat control a solenoid valve to operate the foggers 3 to 5 min every 30 min when pen air temperature exceeds 85 F.

BROODING

Some type of brooder or supplemental heat is required for chicks from one day old through 3 to 6 weeks of age. It is customary to start day-old chicks at a hover air temperature of 95 F and to reduce the thermostat setting 5 F per week through the sixth week, or until the mean daily temperature (inside) approaches 70 F. No attempt is made to control humidity under the hovers. Siegel and Coles (19) reported that the level of humidity in the brooder house had no direct effect on the chicks. Hover space should be 7 to 10 sq in. per chick(16-b).

Either cool-room or warm-room brooders may be used, the former adding little heat to the room and the latter adding considerable heat. Drury (4) reported no difference in chick performance when five types of cool-room brooders were used; but the energy requirements varied markedly with type of brooder‡. Feed conversion by broilers should be better if the room is kept warm (see discussion on ventilation); but the point at which the cost of fuel energy exceeds the cost of feed energy has not been determined for southern conditions. Hertel (7) reported from a survey in California that the net profit from broiler growing decreased as brooder-fuel consumption increased.

Brooding equipment should be removed from the work area, when not in use, to facilitate choring. The space under the rafters is convenient for storing colony brooders. The chore of lifting brooder hovers to inspect the chicks can be reduced by suspending the hovers on pulleys and using counterweights.

‡Brooder types, in the order of increasing Btu requirement per chick were electric underheat, conventional electric hover, heat lamps with hover, cool room gas hovers, and "warm-room" gas hover. (N.B. The cost per Btu is not the same for electricity and gas.)

LITTER AND MANURE HANDLING

From the standpoint of litter cost and humidity control, built-up litter is desirable; but most colleges recommend that broiler litter be removed after each batch of birds is sold. This recommendation is based on the assumption that reuse of litter aggravates the disease problem and reduces growth rates. Litter in laying houses is usually removed only when the hens are replaced. Fresh litter is added from time to time to dilute the droppings and absorb moisture from them.

The moisture content of fresh droppings is 75 to 80 percent, but litter moisture should be kept below 35 percent (wet basis) to prevent caking. Therefore, some means must be provided for removing the droppings or removing moisture from them. Regular removal of droppings may be more economical than the maintenance of high air-flow rates, but this has not been demonstrated. A mechanical pit cleaner, with feeders, waterers, and roosts located over the pit, can remove 75 percent of the droppings, and thus significantly reduce the ventilation requirement (see discussion on ventilation). Auxiliary mechanical equipment can move these droppings directly into a manure spreader. The remaining droppings and litter can be pushed into the pit with a shovel or dozer and mechanically removed. In the absence of a pit and cleaner, all the litter can be removed with a tractor loader dumping into a manure spreader. Litter may be carried into the house by truck or wagon and spread with a tractor dozer. Large doors and adequate clearance are required when farm tractors, trucks, and manure spreaders are used in the house.

In cage laying houses where litter is not used, the droppings are usually allowed to "cone up" and dry out to discourage flies. Flies may also be controlled by frequent removal of droppings, electric fly killers, or chemical treatment of the droppings. Hart (6) reported that mechanical equipment for removing these droppings reduced the cleanout time 50 percent and eliminated hand labor.

Roosts

Roosts are not required for broilers and may not be required for heavy-breed hens, but their use will reduce the floor-space requirements for light-breed layers. Where droppings pits are used, roosts should be located over the pits.

FEED HANDLING

Layers

A study of 27 well-managed egg farms in California showed that automatic feeders reduced feeding labor by 66 percent (5). Other workers have estimated a reduction of 80 to 90 percent in feeding time. Van Arsdall and Cleaver(22) stated that total annual feeding costs are less for mechanical feeders than for hand feeders when flock size is larger than 750 hens and labor costs 90 cents per hour, but Matson (15) reported that 3600 hens would be required to justify the use of mechanical feeders at a labor cost of $1.20 per hr and that hand feeding would be cheaper for all flock sizes when labor costs 90 cents per hr. Self-feeders filled weekly from self-unloading wagons reduce labor requirements nearly as much as automatic feeders (22). Automatic feeding systems for cage layers cost more per hen; and not many packaged systems are available. Work simplification methods such as the use of feed and egg carts may be more economical than the use of present-day mechanical feeders for hens in cages. Forty linear feet of feeder space should be provided for each 100 floor-housed hens (16-a).

Broilers

Johnson (11) and Snyder and Lang (20) reported that the use of mechanical feeders resulted in faster growth, but the same feed conversion as the use of hand-filled feeders. Seagraves (18) reported that total annual feeding costs were slightly less for mechanical feeders in flocks of 6,000 broilers when labor costs 60 cents per hour, and that the saving due to mechanical feeding would increase as flock size or labor rate increased.

Baby chicks require special hand feeding for the first week or more and the height of feeders must be increased frequently as the chicks grow. Furthermore, automatic feeders tend to be in the way during brooding periods and they must be moved from the work area for house cleaning. Suspended feeders which can be easily raised as the chicks grow and can be lifted clear of the work area as desired would eliminate some of the disadvantages inherent in floor-supported feeders. The feeder space requirements, in linear inches per 100 chicks, are as follows: day-old through 2 weeks—100; 3 weeks through 6 weeks—175; 7 weeks through 12 weeks—300(16-b).

Storage

The use of bulk feed makes possible further reductions in labor, but it necessitates special storage and handling equipment. Feed storage should be located near the point of use; and gravity conveying to the feeder hoppers should be used wherever practicable. The feed must be kept dry and vermin must be kept out of it.

LIGHTING

Poultry-house lighting has three purposes: it enables the operator to see to perform his duties, it enables the birds to see feed and water, and it stimulates egg production. In breeding flocks the sexual activity and fertility and hatchability of the eggs may also be affected by light. An average light intensity of 5 foot candles is adequate for usual choring, but higher intensities are required in the egg-service room. Since most of the chicken-house chores are done during daylight, it is doubtful that additional lighting for this purpose would be economical.

Layers

For floor-housed commercial layers an intensity of 0.5 to 1.0 foot candle of supplemental light and a total day length of 12 to 15 hours is considered sufficient to stimulate egg production(19-a). In houses where daylight is excluded and floor space allowances are small, there is some indication that higher intensities may be required. Color (wave length) of light is not critical, but blue and green light does not provide as much stimulation as other colors. Photoperiods other than constant day-lengths are being studied, but general recommendations for these cannot yet be made. Dark schedules occurring at unnatural times necessitate

special construction features including full-time power ventilation through lightproof baffles.

An average light intensity of one foot candle will be provided by bare 50-watt incandescent lamps mounted 7 ft high and spaced 10 ft on centers. The use of reflectors and/or light-colored interiors would permit the use of lower wattage lamps. Laying-house lamps are usually controlled by 24-hr clocks. These clocks are adjusted weekly to add the necessary "on" time to the beginning of the natural day to give a total of 14 hr of light.

Broilers

For broilers, lighted periods approaching 24 hours daily have resulted in faster growth and better feed conversion, but also in abnormal eye development of the birds (16). Quality and intensity of light for broilers has received little attention.

Many growers consider that some low-intensity, all-night light in the broiler house is essential to prevent huddling (with consequent smothering) of the birds. If this is true, automatic standby lighting should be provided for emergencies.

WATERING

Hand-filled watering fountains are used for baby chicks, but automatic waterers are generally used for older broilers and for adult chickens. With float-type waterers 6 to 9 gal of water per day per 100 hens is consumed. The amount increases with ambient temperature. More water will be consumed with continuous-flow systems than with float-type waterers.

Drinking space of at least 96 linear inches per 100 layers, 20 linear inches per 100 2-weeks-old chicks, and 40 linear inches per 100 12-weeks-old broilers should be provided (16-a, 16-b). Some workers have suggested that 30 to 50 percent more feeder and waterer space is needed in hot weather.

Warming devices to prevent freezing of water should be used where the house temperature is likely to drop below 32 F. A table of wattage requirements for electric water warmers is given in USDA Miscellaneous Publication 728. Research has not shown that warming the drinking water to higher temperatures or cooling it in summer is economical, but locating the water pipes underground will minimize the freezing of water and help to keep it cooler during summer. Adequate provision should be made for catching spilled and overflow water and for draining it to the outside.

Regardless of the type watering system used, an elevated reserve tank (with freeze-prevention means) should be connected into the system. This provides an emergency supply as well as a convenient means of adding medication to the water.

NESTS, EGG HANDLING, EGG STORAGE

The type of nest to be used depends upon the housing system, the manner of collecting eggs, and preferences of the hens. With individual or colony cages the hens have no choice of where to lay, but when they are not confined, they prefer nests that are slightly darkened and have padded bottoms. Eggs in rollaway nests cool faster, stay cleaner, and are easier to gather; but more eggs may be laid on the floor. Early training will encourage hens to use nests. The arrangement of nests for efficient egg collection is important whether eggs are gathered by hand or automatically. Body temperatures of hens may rise 2 F while laying (23); therefore, nests should be in the path of cool air during hot weather, but they should not greatly obstruct the air flow to other parts of the house.

Work simplification methods and equipment for hand gathering can reduce the egg handling time by reducing the rehandling for cleaning and packing. Mechanical egg gatherers which eliminate gathering labor in cage systems and reduce it to the gathering of floor-laid eggs when hens are kept on the floor or litter are available. With present-day systems, manual handling is required from the collection point to the egg cleaner. Since egg collecting, cleaning, and packing constitute more than 75 percent of the total chore time for commercial egg flocks, more effort to develop completely automatic egg handling systems may be justified (1-a).

To preserve quality, eggs should be kept in refrigerated storage on the farm until they are delivered to the wholesaler. This storage should be designed for rapid cooling and holding of adequate quantities of eggs at the proper temperature and humidity. Bulletins are available on the design and operation of egg storage rooms.

ARRANGEMENT OF COMPONENTS

It is important that each of the various components be related to the total enterprise so as to achieve maximum economy. Detailed plans for structures and for equipment layouts are available from the land-grant colleges, the USDA, and from manufacturers.

SUMMARY

Poultry house environment is important for the health and productivity of the flock, and it influences the life of the building. Good ventilation, sufficient insulation, and emergency cooling promote bird health and comfort and aid in the removal of moisture to maintain dry litter and prevent excessive condensation on building surfaces.

The use of mechanical equipment saves labor and will result in over-all economy for larger flocks when labor costs are high or moderately high. The arrangement of equipment, storage areas, and work areas to save labor and promote product quality will contribute much to the economy and make the chores less disagreeable.

Further research on the environmental requirements of poultry, development of labor-saving equipment, planning of layouts, and comparative cost studies of housing, equipment and management methods will provide data with which the agricultural engineer can design poultry houses and equipment for the greatest net return.

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SWINE

Swine Housing

O. Burr Ross

Requirements for confinement system of production

CHANGES in swine production nearing revolutionary proportions is taking place, or will appear on the horizon in the near future. While the practicality of confinement systems of swine production has been demonstrated over and over again by research institutions, universal acceptance by swine producers has been slow.

I shall not attempt to summarize the results of research relative to the economic desirability of confinement systems of swine production versus non-confinement systems. This conference is predicated on the premise that confinement rearing of swine is economically sound, yet I cannot refrain from posing the question: "Why haven't more swine producers adopted this method of production?" Perhaps the answer is self-evident, yet in the minds of many the use of pasture and existing equipment has considerable merit. It could well be that the availability of capital or the lack of a transition program enabling producers to use existing equipment in some manner creates a mental and economic road block preventing universal acceptance of the confinement system. Relative efficiencies of production resulting from use of any particular system will no doubt dictate the degree of acceptance of basic swine-producing systems. I believe that most of the hogs of tomorrow will be raised under some sort of confinement program.

At the outset, we must evaluate swine shelters and equipment in the same manner as we might evaluate any other capital item such as a tractor or other farm machine. A critical assessment of the earning potential must be made. Many factors, of course, will influence the final evaluation but the basic consideration of a swine producer must be one of economics.

I am confident that engineers can build almost anything if those of us concerned with swine production could, with assurance, tell them exactly what is needed. Unfortunately sufficient facts are not available for us to give you rigid specifications enabling you to build a shelter which will provide an optimum environment for all seasons of the year in all areas of the country.

Research in the swine industry has been directed principally toward the nutritional, breeding and physiological areas, and environment and physical problems have been virtually unexplored. Management and environmental research is the most neglected field of investigation in the area of swine production today. Engineers and swine production specialists have, for the most part, worked independently and the facts so developed are many times confusing. Only by close cooperative effort between these two groups can reliable information be secured which will eliminate confusion and provide a basis upon which sound recommendations can be made.

The extensive new swine research program, being initiated here at the University of Illinois, will, I believe, provide facts which should be illuminating. The departments of animal science and agricultural engineering at this university are working cooperatively in an effort to study certain specific environmental, engineering and management problems. This kind of research is very expensive. It has been our hope that the completed plant will be an engineering and production laboratory useful not only to the swine producer but to the building and equipment industry as well. While we have a considerable amount of money to invest in this laboratory consisting of some nineteen 15-litter houses, we will not be in position, independently, to construct buildings using most kinds of building materials or designs in use today. We had hoped that the building industry might share our enthusiasm and provide substantial help to further this work.

I shall not attempt to enumerate the many reasons why year-round or multiple farrowings have increased in popularity among producers. Efficient use of expensive buildings undoubtedly would rank high on the list, and we must consider this factor as we advise producers relative to buildings and equipment.

We are asked many questions today which we are unable to answer factually. Only by cooperative effort of all interested parties can such facts be developed from which concrete recommendations can be made. A basic and fundamental problem facing the producer is the economic desirability of a one, two or three-building system. A one-building system would be defined as a house so designed to be adequate for farrowing, nursing and finishing with the pigs remaining in the building until they are marketed. A two-building system would consist of one building adequate for farrowing and nursing and the pigs then moved to another building for the finishing period. A three-building system would consist of three buildings, one for farrowing, one for a nursery and the third for the finishing period. As I see it, opinions rather than facts dictate the recommendation which is made to an individual producer.

The questions of heat conservation and ventilation are extremely important facets of swine production for which too little carefully controlled experimental information is available. Is it more economical to insulate buildings and conserve body heat or dissipate the body heat and depend upon feed for its replacement? Perhaps an even greater problem is the control of moisture coming from the animals. Ventilation systems which will do much to control moisture in houses dissipate the body heat. What combination of ventilation systems, building design or insulation will achieve maximum economics in this area?

In temperate climates we frequently are more concerned with the proper environment during cold weather than during hot weather. From the producer's standpoint they are equally important. To be sure, extremes during the winter pose a problem particularly for farrowing, but I am sure most producers today would rather farrow when outside temperatures are −20 F than when the temperature is +95 F. No doubt we would agree that heated farrowing houses, heat lamps and other heating equipment have done much to lessen the fear of farrowing in cold weather. I am not sure that we can say the same about the equipment or housing designed to eliminate the hazards of farrowing during hot weather. The economy of using air-conditioning equipment and techniques for farm livestock is virtually an unexplored area. With existing equipment we have difficulty, during hot weather, of luring the pigs away from the sow to prevent her from stepping or laying on them. We have methods which are quite satisfactory to accomplish this during cold weather. Heat itself is generally very attractive to baby pigs during the cold weather and can be used to entice the pigs to nest in an area away from the sow.

Diseases and parasties constitute the greatest single denominator for successful swine production and consequently must be a determining factor in any building design. The disease level of a particular herd frequently is the unknown factor. We have gone from large central units located at the farmstead to portable buildings and equipment in clean pastures as a means of combating diseases and parasites. It is recognized that intensifying animal populations in a given area increases the disease hazard in geometric proportions. Many large swine buildings stand today as empty monuments to the conquest of swine diseases on that farm. The so-called "wonder drugs" and other chemicals have made it possible to live with certain diseases and today the movement is away from clean pastures to confinement systems. I am hopeful we are smarter than our fathers were and can cope with the disease problem. I am confident we know more about disease problems today and how to live with them than they did. We must, however, be mindful of this problem as we design facilities for confinement rearing of swine. Ease and thoroughness of cleaning must be considered carefully.

There is some evidence that the level of non-specific disease organisms builds up to dangerous proportions under the best of conditions. There is much to be said regarding the efficiencies of labor and maximum utilization of equipment which can be achieved with large central units, but the

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disease problem might again rear its ugly head and render extremely large single-production plants useless. Because of this there may be considerable merit to designing small units to control disease more adequately. The optimum size of a single unit is a matter of opinion, but there are some who from experience feel that the farrowing unit, as an example, should handle no more than 10 to 15 sows. Others feel that the unit size should be smaller. I personally can only shudder and hope when I hear of units designed to handle from 30 to 50 sows. Unless some miracle for controlling disease during the first six to eight weeks of the life of the pig is developed they too could become empty reminders of poor planning.

It is much too early to predict the ultimate impact which the so-called "disease-free" pig production program will have on our thinking regarding size, design and equipment for swine houses. It is mathematically possible to repopulate farms with disease-free hogs in a very short time. The total production of hogs in Illinois could be produced from such parents in a matter of five years or less very easily if the program is sound and is accepted by producers. I feel this program has considerable merit and would predict that widespread adoption of it will occur before we collectively are in position to provide factual information for the producers in the area of housing, equipment, nutrition, sanitation and breeding.

I shall mention briefly the need for improvement in certain other areas. You are mindful of the crying need for more efficient methods of handling feed and manure. Automation is, I believe, the correct nomenclature for any idea or program which conserves labor and approaches a push-button operation. Machinery to handle feed for full feeding operations appears to be available today. Machinery capable of providing limited amounts of feed to each animal is only in the developmental stage. We have no economical mechanical method for feeding limited amounts of feed to sows and must resort to hand labor. Facilities for handling manure are on the market, but my observation leads me to believe we have not solved the problem in its entirety. Floors which will allow the manure to fall into a pit below such as slats, wire, expanded metal, etc., might have merit if the kind of floor does not impair the value of the animal. As you know, confinement of pigs to concrete for periods of months creates abnormalities of the feet and legs. These abnormalities may be eliminated by selective breeding programs yet I am sure it is not in the realm of impossibility that some kind of floor might partially solve the problem.

I have said nothing about space requirements, lighting, animal-behavior aspects, nutrition, breeding or meat quality. We think we know much about certain of these areas, but I am sure that the pig must be asked additional questions as his environment is altered if we are to achieve maximum efficiencies. Too often we design buildings for the comfort and well-being of the caretaker rather than the comfort and well-being of the pig. The biologist and engineer must work as a team if real progress is to be made. The only counsel I can give is that shelters be designed and constructed with the health and well-being of the pig in mind and adapt his requirements to the human side of the equation.

Functional and Basic Requirements of Swine Housing

Production approaching conditions of controlled confinement

T. E. Hazen and D. W. Mangold
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WITHIN the past few years, many swine producers have changed from pasture to building and pen confinement production. Many are now on the threshold of practicing a type of production which can be called controlled confinement. This newest method surrounds the animal with an artificial environment from birth to market age. Because of its newness, there are still problems to be solved before it will be accepted fully by the majority of swine producers. On the other hand, confinement already has met with acceptance, particularly in areas of high land value, so there will be a transitory period during which design for both confinement and controlled confinement are in demand. The management of one will vary from the other in certain aspects due to differences in environmental control within the building types. Fig. 1 illustrates what might be a typical flow diagram of each system.

Starting with the sow-boar-gilt housing area, the two systems are almost identical up to the time the pig is weaned. At this point, depending upon the farrowing schedule, either the pig is left in the farrowing building until 40 lb of weight and then moved to an open-type finishing unit; he is moved at 10 to 12 lb (at approximately three weeks of age) into a growing unit where he is left until he reaches 40 to 50 lb and then moved into the open-type finishing unit; or, if a controlled confinement system is used, he may be directly moved from the farrowing to the finishing unit at any time after he reaches 10 to 12 lb of body weight.

The reason for these management procedures becomes apparent after examining the reaction of swine to their environment.

Heat, Moisture, and Odor Production

The hog is believed to have originated in the tropical swamps. Over the years he has evolved into a somewhat different animal from his predecessors, but he remains a non-skin-sweating homeotherm. Total heat production from the hog can be subdivided into two forms; sensible heat from the body surfaces governed by the heat transfer laws of conduction, convection, and radiation, and latent heat from the lung cavity by adiabatic saturation of an air-water vapor mixture.

Brody (4)* found that basal heat production in most homeotherms closely follows the equation

$$Q = KW^{0.734}$$

in which Q is the heat production expressed in Btu per hour, K is a coefficient, and W is the weight of the animal in pounds. By properly estimating the value of K, the total heat production of the animal can be approximated within the temperature range of 40 to 80 F. For basal condition, Brody found the value of K to be about 6.5. A fairly good estimate of K for normal activity is two and one-half times that of basal, although experimental results such as reported by Bond (1) will show a range of K from 14 to 18 for market weight and newly weaned pigs, respectively. Above and below the 40 – 80 F range, temperature stress produces physical and chemical changes which render this equation invalid. Therefore, where design temperatures surrounding the hog fall outside this range, or where more precise data is required within this range, the reader is referred to calorimeter studies conducted at the University of California (2).

To be useful in design, total heat production must be subdivided into its latent and sensible components, since the latent heat is a measure of moisture production and the sensible heat a measure of energy available for changing temperature. Fig. 2 illustrates the quantitative values of total heat, sensible heat, and latent heat for a 125-lb hog in the temperature range of 40 to 100 F. Since there does not seem to be appreciable difference percentagewise in the subdivision of total heat with varying animal weight, use of a multiplier based on Brody's equation makes it possible to translate values for any weight of pig (Fig. 3). From observations, if animals are penned in groups as opposed to being penned separately, the effect on

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*Numbers in parentheses refer to the appended references.

. . . Swine (Functional and Basic Requirements of Housing)

heat production is approximately the same as if the temperature scale in Fig. 2 covered the range of 35 to 90 F. This is largely due to a decrease in radiation loss from the surface of the animal by virtue of seeing other animals rather than surfaces with approximately the same temperature as the space. Heat production below 40 F has not been well investigated, but it is known that an increase in feed consumption and physical exertion of the pig takes place. Consequently heat production begins to rise rapidly as a result of increase in sensible heat. Above approximately 70 F, feed consumption begins to decline accompanied by a decline in heat production. If temperatures go high enough, virtually all of the total heat is in the form of latent heat and polypnea is evident. Whether the temperature is constant or cycling (fluctuating) seems to make little difference as long as the mean of a cycling temperature is approximately that of the constant temperature and variations above or below this mean do not exceed approximately 10 F (20 F total) in a 24-hour period.

Odor control appears to be more desirable in terms of building life and management satisfaction than in animal performance. Some producers feel that heavy odors weaken the respiratory organs and leave pigs more susceptible to disease. The primary odor is ammonia resulting from fecal wastes, and its production rate is temperature and moisture sensitive similar to that of chemical reactions for organic compounds. In other words, the presence of some moisture is required for forming the compound and the rate of reaction is increased exponentially with increase in temperature. Freezing almost entirely stops the formation of ammonia; the rate of production is then uniform up to approximately 55 F, and based on ventilation rates required to hold concentrations at a given level, production practically doubles with a temperature increase from 55 to 80 F. What might be termed a clean atmosphere contains under 15 parts per million of ammonia, readily detectable approximately 30 parts per million, irritating approximately 70 parts per million and toxic about 200 or more parts per million concentration. Where daily cleaning is practiced and the ventilation rate is sufficient to control moisture, odor also is fairly well controlled. This probably explains why more precise data on odor production are not available. However, in controlled-confinement systems odor becomes a much more important factor and may well become the limiting factor in terms of economy of mechanical refrigeration equipment.

Effect of Temperature and Humidity on Production

One would anticipate from a purely physical analysis that the larger animal would be more tolerant to cold and less tolerant to heat, due to decreasing surface exposure per unit of volume with increasing size. This in fact does appear to hold true with pigs from 50 lb to maturity. It also appears to be true of the baby pig but perhaps because of an undeveloped regulatory mechanism. It does not appear to hold true, at least in terms of average daily gain and feed conversion, for weaned pigs between 12 and 50 lb body weight (10). The growth period from 12 to 50 lb has not been studied sufficiently to offer an explanation of this lack of temperature effect. It may be that because the pig at this stage is highly efficient and under a genetic period of rapid growth in terms of percentage increase in body weight, studies which have emphasized average daily gain and feed efficiency must now redirect their efforts to measure environmental influence in immediate terms of disease resistance and mortality, or later effects on feed efficiency and average daily gain.

Fig. 4 shows the normal growth rate of a pig if raised under reasonably good conditions and nutrition. Fig. 5 shows anticipated feed efficiency in terms of pound of feed per pound of gain. To show the effect of temperature on this normal performance, Figs. 6 and 7 illustrate the deviation for the various stages of pig production. It will be recognized that the level of nutrition (feed energy) can materially affect these deviation patterns. Work is now under way at Iowa State University which should provide information on temperature-nutrition interaction.

Limited and self-feeding also cause differences in feed efficiency, fairly good evidence being available that growing-finishing pigs require the least feed per pound of gain when about 75 to 80 percent full fed. This could explain the improvement in feed effi-

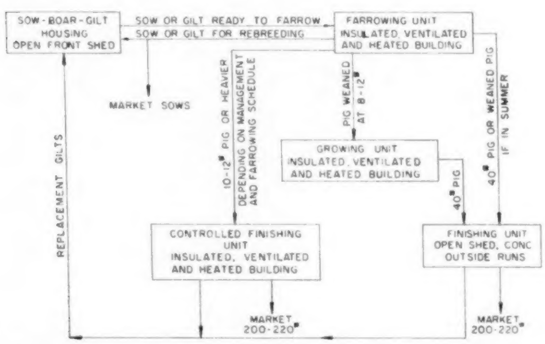

Fig. 1 Basic housing systems used in confinement production

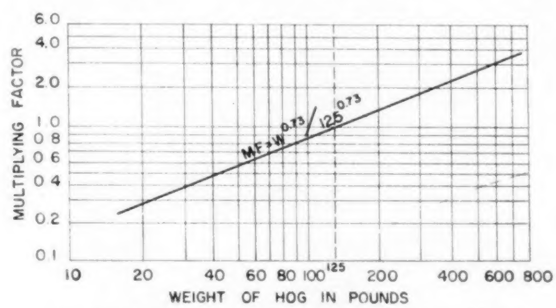

Fig. 3 Multiplying factor to find heat production of hogs weighing other than 125 lb

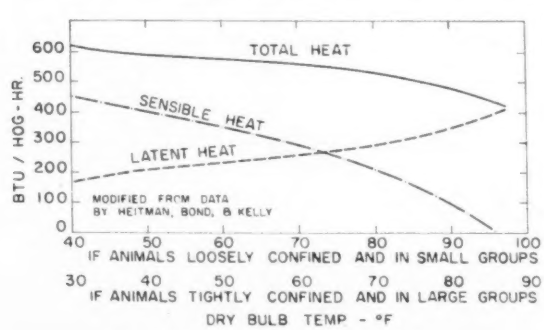

Fig. 2 Heat production of a 125-lb hog

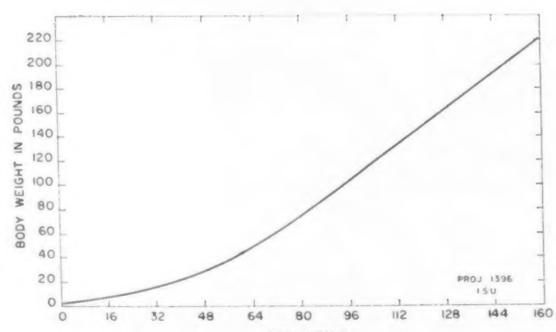

Fig. 4 Growth rate of hogs with good feeding and housing

ciency found in the Iowa tests where growing-finishing pigs were exposed to moderately high temperatures, since high temperatures tend to limit the amount of feed intake. If temperature was increased further, it would be anticipated that feed per pound of gain would increase as found in the California studies (1), since the appetite would be restricted beyond the point of maximum efficiency. On the other hand, average daily gain consistently shows a decline with temperatures above the optimum.

Where temperatures fall below the optimum range, both average daily gain and feed efficiency decline primarily because of a conversion of feed to fuel. Clausen (6) reports that carcass value also declines with low temperature because the pig can convert proteins into heat much more easily than carbohydrates. Thus too cold a temperature results in not only less efficient and slower growing pigs, but fattier pigs. Offsetting fattiness by increasing protein in the diet is limited not only because it is expensive, but because a pig can assimilate only so much protein.

Humidity seems to have little if any effect on the growth efficiency of swine unless high humidity is accompanied by thermal stress. The exact importance of humidity in terms of growth of disease organisms is not well known. Effects of high humidity on building material and equipment life is known to be detrimental. However, some American and European producers are having good success with pig performance where relative humidities are 90 to 100 percent and temperatures simultaneously kept between 60 and 80 F. High humidities result in lowered ventilation rates and in recapturing some of the latent energy by condensation on the building surfaces. Thus it is possible to keep the building temperature between 50 and 60 F during the winter in the north central region and without supplemental heat. However, until the economics of more rapid deterioration of buildings and equipment and effects of high humidity on disease propagation are understood better, a deliberate design of this nature could have very serious consequences. Under these conditions, odor production probably will be the limiting design factor.

Drafts

Many experiments are found in the literature where conditions are described in total as drafty. Normally this means that there is an undesirable air motion and the natural interpretation is that the air velocity must be too high. Research on humans has established draft by descriptive sensation of the humans subjected to the various air motions, relative humidities, and temperatures. Fig. 8 is a representation of the type of plot obtained in terms of people objecting to draft (8, 9). This indicates draft is more than air velocity; it is also a function of temperature and relative humidity of the air, and condition and temperature of the surface over which the air is passing. No information similar to this graph is available on swine, but it does give a clue as to alternative methods for controlling drafts. If moisture and odor produced by the animals are to be removed by ventilation, a certain amount of outside air must be brought into the building and distributed.

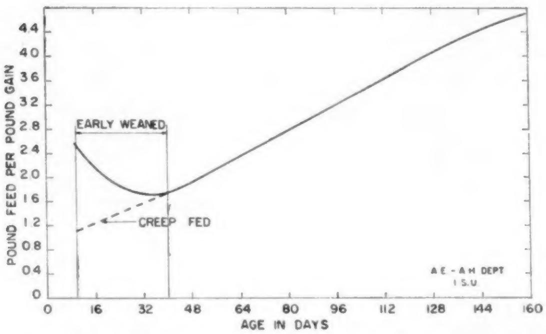

Fig. 5 Feed efficiency of pigs under good feeding and housing

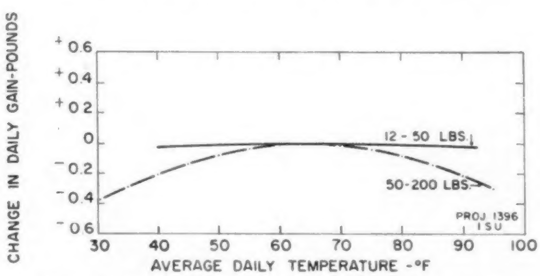

Fig. 6 Deviation of average daily gain with temperature

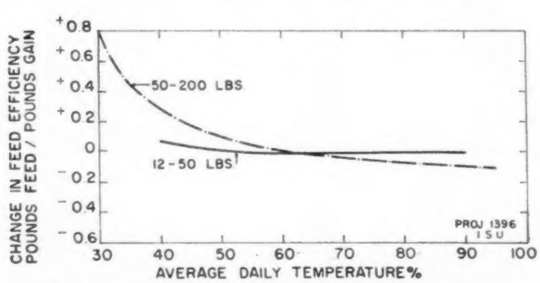

Fig. 7 Deviation of pounds of feed required per pound of gain

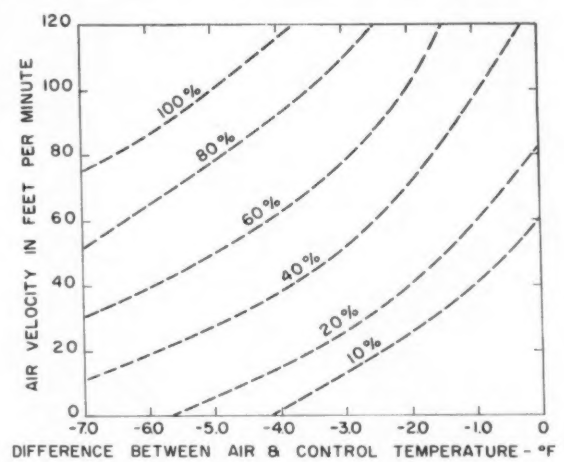

Fig. 8 Percentage of human accupants objecting to drafts in air-conditioned rooms (9)

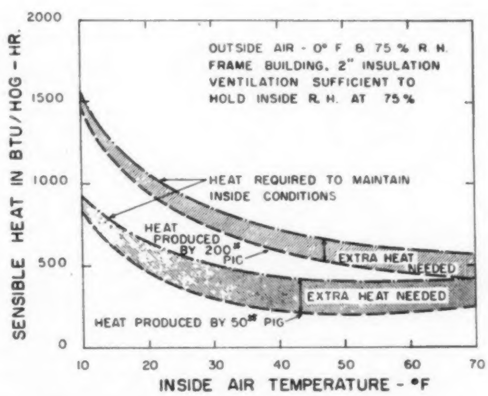

Fig. 9 Supplemental heat required for maintaining inside temperature when 0 F outside

In many cases, particularly where there is a large differential between the inside and outside temperatures, necessary amounts of air can create draftiness even though the velocity is low. The concept presented here indicates this air motion can be maintained without drafts by adding sensible heat to the air prior to the time it comes into contact with the animal. Since a heat balance of a swine-production unit reveals there is inadequate sensible heat production by the animal to maintain wide temperature differentials between outside and inside if ventilation is adequate to remove the moisture produced, the required supplemental heat could be used effectively to prevent drafts by preheating ventilating air. In any event, drafts can be prevented if the combination of velocity and air temperature are designed to be neutral with the condition and temperature of the animal's surface.

Influence of Light

It has been fairly well established that swine production is not influenced significantly by light. For some years, environmental research on swine at Iowa State University has been conducted in windowless houses where pigs have been produced, for all practical purposes, in total darkness. There has been no evidence of loss of performance when compared with animals produced under normal diurnal lighting. Braude and others (3) have shown that length of lighting did not influence feed intake or performance of pigs from nine weeks of age to market weight. Catron and Facto (5) have studied the influence of light intensity on feed intake through use of time lapse cinematography. Their studies are yet inconclusive but indicate baby pigs eat more in the daytime than at night even under constant illumination. Therefore, on the basis of knowledge to date, light appears to have only minor, if any, influence on hog production.

Basic Requirements of Ventilation, Insulation, Heating, and Cooling

It does not seem practical to separate ventilation, insulation, heating, and cooling since the requirement for each is dependent upon the value established or arbitrarily selected for the others in the over-all heat and moisture balance. This interaction is most easily demonstrated in a typical calculation of requirements.

The first step is to select the maximum relative humidity which can be tolerated inside the building. The higher the relative humidity permitted, the less will be the quantity of air required to remove the moisture produced. This follows directly from an examination of the psychrometric chart which in turn is a graphical illustration of the behavior of air-water vapor mixtures. Practically speaking, the maximum relative humidity in animal housing is between 70 and 80 percent, if condensation on the building surfaces is considered undesirable and appreciating the normal inability to make all parts of the surfaces meet the average design for thermal conductance.

The second step is to select an outside design temperature and an inside design temperature. The minimum and maximum outside design temperatures are, respectively about 15 to 20 F above the normal minimum temperature and the normal maximum daily mean temperature expected each year. The inside air temperature is either the average of a 20-deg F diurnal range if cycling temperatures are used or a constant temperature based on production performance and compromised with economics.

Now let use examine a situation which might be typical of a north central design: The subject is a finishing house for pigs growing from 50 lb to a market weight of 200 lb. Several weights of animals are in the house at any one time but assume they are so proportioned that the heat and moisture production is the same as if all the pigs weighed 125 lb. It is desired to maintain the temperature inside the building at 50 F and the outside design temperature is 0 F. A maximum relative humidity of 75 percent is selected so that surface condensation on the inside faces of the building does not exist. There are approximately 15 sq ft of wall and ceiling surface for each animal within the building. The problem is to find: *(a)* the required resistance of the wall and ceiling surfaces to prevent condensation, *(b)* the ventilation rate required for moisture and odor control, and *(c)* the additional amount of ventilation or supplemental heat required to maintain the space temperature at 50 F.

(a) From the psychrometric chart it is observed that air at 50 F and 75 percent relative humidity contains 0.0057 lb of water vapor per pound of air, and that if air at this condition is cooled to 43 F, it is now saturated and condensation will occur. Therefore, the inside surface temperatures must be 43 F or above. From the equation

$$R_t = R_{fi}\,(T_i - To)/T_i - T_s$$

where T_i is the inside temperature, T_s is the surface temperature, T_o is the outside temperature, R_{fi} is the resistance of the inside surface air film, R_t is the required total resistance of the wall. Substituting, it is found R_t must be 4.28 or higher. A wall with one inch of blanket insulation normally will provide this resistance.

(b) The psychrometric chart shows air at 0 F and 100 percent relative humidity to contain 0.0008 lb of moisture per pound of air. Since the quantity of moisture at saturation which can be held by air this cold is very, very small, relative humidity at 0 F has little significance on the moisture-carrying capability of air heated to 50 F. Therefore, only a very small error would be introduced if the actual relative humidity at 0 F is something under 100 percent but the design based on 100 percent. Taking the two conditions of 0 F and 50 F, the air has a capability of picking up 0.005 lb of moisture for each pound of air introduced through ventilation. From Fig. 2 it can be observed that at 50 F a 125-lb hog produces approximately 190 Btu per hour in the form of latent heat.

Dividing 190 by the latent heat of vaporization (1035), the number of pounds of moisture (0.184) produced per hour through respiration is obtained. Assuming that the air is well distributed and that each pound of ventilating air picks up its full capacity before being discharged from the building, 36.7 lb of air per hour per hog would be required to remove respired moisture. Depending upon the management of manure removal, amount of spillage from waterers and quantity of evaporation from the floor, some additional ventilation would be required to maintain humidity at the desired level. In other words, the 36.7 lb of air per hour is the ***minimum*** rate of ventilation per hog.

(c) To bring air from 0 F to 50 F requires sensible heat. In this particular case the heat required is obtained by multiplying the number of pounds by the number of degrees of temperature rise and the specific heat of air at constant pressure, or

$$Q_{va} = 36.7 \times 50 \times 0.24 = 440 \text{ Btu per hour}$$

The wall and ceiling losses computed from

$$Q_w = A\,(T_i - T_o)/R_t = 15(50)/4.28$$
$$= 175 \text{ Btu per hour}$$

Thus the sensible heat required is 615 Btu per hog-hour. Since the sensible heat production of a 125-lb pig at 50 F is about 425 Btu per hour, to maintain this condition requires 190 Btu per hog-hour of supplemental heat.

A natural inclination is to let the inside temperature fall or increase the insulation rather than provide supplemental heat. The latter is theoretically possible, but since reduction of wall loss to zero would save only 175 of the 190 Btu per hour needed, it may not be practical. The alternative of reducing inside temperature also may not be profitable because *(a)* loss in gain and efficiency may be more than cost of heating and *(b)* reduction in moisture-carrying capacity of air may be more rapid than gain in sensible heat production.

For example, at 40 F and 75 percent, air can hold 0.0040 lb of water per pound of air or 0.0017 lb per pound (30 percent) less than at 50 F. Moisture production in the form of latent heat has reduced to 180 Btu per hog-hour, or by 5 percent. Sensible heat production has increased very little. Also 52.5 lb per hour per animal of ventilating air are now required, so

$$Q_{av} = 504 \text{ Btu per hog-hour}$$

The wall and ceiling loss is 140 Btu per hog-hour. Consequently the total sensible heat now required is 644 Btu per hog-hour, and the deficit is 194 Btu per hog-hour or slightly more heat than required at 50 F. A summary of heat balances for 0 F outside with varying temperatures inside is given in Fig. 9.

The previous figures are based on ventilation for latent heat only. Some moisture evaporates from the floor and manure, and this absorbs about 1035 Btu per pound of moisture evaporated, and additional ventilating air to remove it. At 50 F and with once a day cleaning it is estimated that

about 0.03 lb per hog-hour is moisture in this form. This is an additional sensible heat load for ventilating of 70 Btu per hog-hour plus 30 Btu per hog-hour for heat of vaporization. Therefore, total sensible heat required is now 715 Btu per hog-hour, and total supplemental heat required is 290 Btu per hog-hour.

If supplemental heat is not added, either the moisture and odors must be allowed to accumulate or the building temperature and ventilation varied until a balance occurs. One balance point is obviously where the inside is the same as the outside. The other balance point must be found by trial and error and will probably occur with the inside a very few degrees above the outside during periods of low temperature, and perhaps as much as 25 F above that outside when the outside temperature is 25 F or above. If, for example.

$t_o = 30$ F and $RH_o = 75$ percent
$t_i = 50$ F and $RH_i = 75$ percent

then the air required for ventilation is 58.8 lb per hog-hour.

$Q_{va} = 353$ Btu per hog-hour
$Q_w = 70$ Btu per hog-hour

and total required sensible heat is 423 Btu per hog-hour. The sensible heat produced by a 125-lb pig is 425 Btu per hour so the system is in approximate balance.

Summer cooling is much the same procedure as heating, except that ventilation is reduced to that amount required for odor control and the moisture is removed by condensation on the refrigerated coils. This means the coil temperature must be at or below the dewpoint temperature of the desired air condition. The depression of the coil temperature below the desired inside condition dewpoint will be dependent upon the amount of air passed through the coil and the coil design.

Assume a design condition of

$t_o = 95$ F $\quad RH_o = 60$ percent
$t_i = 75$ F $\quad RH_i = 70$ percent

and the same 125-lb hog equivalent. Since odor production increases sharply with temperature, fresh air will be introduced at the rate of 6 cfm per hog, or 33 lb per hog per hour.

The ventilating air must be cooled to 65 F if the final air condition is to be 75 F and 70 percent. This requires cooling of 12.6 Btu per lb so that

$Q_{va} = 418$ Btu per hog-hour.

Latent heat production is 280 Btu per hog-hour and sensible heat is (310 − reheat for air) or 230 Btu per hog-hour. The wall gain is

$Q_w = 140$ Btu per hog-hour based on the sol-air method.

Total refrigeration load is therefore the sum of these, or 1068 Btu per hog-hour.

If daily cleaning is not practiced, the ventilating rate used here is insufficient and may in fact double. The major load on the refrigeration system being for odor control suggests that mechanical cooling will be inhibited in use until a less expensive method of odor control is developed.

Cooling by sprinkling systems appears to hold promise. However, very little real design data is available regarding air temperatures at which sprinklers should be used, water temperature and rate, and air motion and quality. Some theorizing could be done by observing the division of sensible and latent heat production with temperature. It is obvious that any cooling fast becomes of little advantage below 75 F. Therefore, the object would be to create a synthetic environment producing the same effect as if the animal were in a natural environment of or slightly below 75 F. If no heat was obtained from the air to evaporate moisture from the animal's skin, it would be necessary to evaporate only sufficient moisture to remove the sensible heat production at 75 F, or about 260 Btu per hr for a 125-lb pig. This would mean an evaporation rate of approximately ¼ lb per pig per hour. At the same time it is necessary to provide adequate ventilation to keep the dewpoint at or below that normally occurring at 75 F so that the respiration capacity of the pig is not affected. This means increasing the air-flow rate. However, the air passing over the animal does contribute heat for evaporation and the extreme would be adiabatic saturation. This effect of adiabatic saturation not only lowers the dry bulb, but it raises the dewpoint thus lowering the effectiveness of lung respiration. Therefore, if sprays are to be most beneficial, evaporation should not occur prior to the time the water reaches the animal surface (the coarser the spray, the better), and a high volume of air per volume of water would need to be used.

In practice fairly good success is obtained with ventilation rates of 15 volume changes per hour and over, and sprays used only when temperatures are 80 F or above. Where sprays are used in cooler temperatures, chilling of hogs can occur.

Use of evaporative coolers is best confined to arid regions. Since this is an adiabatic process of passing air through a wetted mat, the final dry-bulb temperature of the air approaches the initial wet-bulb temperature prior to introducing the air into the building. If the wet-bulb depression is small, as is generally the case through the north central region, evaporative coolers may even be detrimental since they cannot cool the air sufficiently to relieve thermal stress and simultaneously saturate the air making lung respiration and skin evaporation more difficult.

Animal Handling and Space Needs

A pig is considered by some to be the most intelligent of domestic production animals. Contrary to popular belief he is extremely clean in habit, only becoming dirty and odoriferous when forced so by unclean surroundings or thermal stress. Therefore, dunging alleys and bedded areas can be used successfully. Handling a pig in an abrupt or angry manner or moving him from one surrounding to another generally causes a setback of from two to three days in growth.

The natural strength of a pig and particularly his ability to use his nose means equipment must be of sturdy construction; feeding and watering equipment can be fitted with self-closing covers, and easily reached and operated latches result in loose animals.

Like most animals, the pig will not normally jump a barrier he cannot see over or through. Therefore, solid partitions need not be more than 6 to 8 in. higher than the animal. If open partitions are used, they should extend at least 12 in. above the animal.

The pig's hooves are not suited to slick surfaces. Consequently floor surfaces need a roughened texture which can be accomplished by finishing concrete with a stiff-bristle broom. Continuous confinement on hard surfaces may lead to lameness, but this can usually be overcome by selection of animals and nutrition. Where housed on new concrete, some hoof troubles occur from cutting by sharp sand. Eventually those particles are worn off and this trouble ceases.

Pigs will walk up ramps if stable footing is assured. They tend to jump even low curbs. They will more readily drive into a pen, scale, or trailer if they can see past the point of intended destination and if not hurried. They will remain more quiet, on the other hand, if they cannot see out of the enclosure. Pigs are gregarious by nature and should not be penned separately for extended periods unless they can see other pigs.

Floor heat has made it possible to produce pigs with little or no bedding. However, floor heat under a lactating sow can result in loss of milking and udder infection. Also some bedding may be desirable at first where dunging alleys are used to help train new pigs.

Sows object to confinement just prior to farrowing. Therefore, stalls should be heavily constructed and dimensioned to prevent the sow from turning or jumping out. In particular provision should be made to prevent backing up and crushing of pigs against the back of the stall during farrowing.

Pigs have a distinct social order. Therefore, designs should be arranged to prevent barring of feeding or watering equipment by the boss animal. Also minimum shifting of pigs is desirable since any new pig must face the task of fighting for position in the social order.

There is still much discussion on how many animals should be confined in one pen or one building. Generally, it is felt that groups much over 40 to 50 animals in a single pen are difficult to manage and that the larger the number of animals housed together the greater the disease risk. However, these factors are largely one of management ability and therefore difficult to rationalize through research.

Current research using time-lapse cinematography (7) indicates there may be arrangements of feed, water, and bedded areas which are preferred by the pig. Although this work is incomplete, such studies will undoubtedly provide helpful design data.

However, it will always be the individual designer's responsibility to adjust data to best meet the individual producer's situation. With this in mind, several tables are presented which are based on research or current practice; these tables constituting what is believed to be minimum allowances.

TABLE 1. SPACE REQUIREMENTS FOR SWINE IN SQUARE FEET PER ANIMAL*

	Enclosed confinement	Open Shed	
		Concrete lot	Shelter
Sow and litter	35	30	40
10 to 40 lb	4	4	2
40 to 80 lb	5	5	3
80 to 120 lb	6	6	4
120 to 160 lb	8	8	6
160 to 200 lb	10	10	8

*Does not include space allowance for alleys. These recommendations are based on current practices in confinement production.

TABLE 2. SPACE REQUIREMENTS FOR MATURE SWINE IN SQUARE FEET PER ANIMAL*

	On Concrete		Dirt Lots	
	Shelter	Lot	Shelter	Lot
Gilts	10	15	15	100
Sows	12	15	20	150

*Based on current practices in confinement production.

TABLE 3. FEED AND WATER CONSUMPTION AND MANURE PRODUCTION OF SWINE, IN POUNDS PER DAY-ANIMAL

Weight lb	Feed	Water*	Manure	
			Feces	Urine
12-40	1.7	3.0†	0.7	1.5
40-80	3.5	6.5	2.7	2.9
80-120	5.5	10.0	5.4	6.1
120-160	6.5	12.0	6.5	8.1
160-200	8.0	14.0	8.5	9.1
Gestating sow‡	7 to 8	18 to 20		
Lactating sow§	12 to 14	42.0		

*Modified from Exp. 811, 975 A. H. Dept. I.S.U. and temperatures between 40 and 70° F. Add 50 percent to water requirements for summer conditions.

†Estimated on basis of dry matter consumption.

‡Estimated on basis of dry matter intake, daily gain, heat production and water consumption for 40 to 70 F temperature range. Add 30 percent to urine production under summer conditions and add any bedding to solid production.

§Complete ration with 15 percent protein.

TABLE 4. FEED AND WATERING SPACE

Weight	Hand fed or watered	Automatic waterers	Self-feeders
lb	lineal foot per animal	animals per cup	animals per lineal foot
12-50	½	25-30	6-8
50-100	¾	25-30	5-6
100-150	1	20-25	5-6
150-200	1¼	20-25	4-5
Sows	2	15-20	*

*Self-feeding not normally recommended because of inability to control weight.

TABLE 5. LENGTH, WIDTH AND HEIGHT OF SWINE*

Weight, lb	Length, in.	Width, in.	Height, in.
6	13.9	3.7	8.2
20	23.6	5.7	14.3
50	30.9	8.3	19.5
100	37.3	9.8	22.5
150	43.5	11.1	25.7
200	48.0	13.4	28.9

*Average of ten crossbred pigs of each weight. Crossbreeding Duroc x Landrace x Poland China (Animal Husbandry Department, Iowa State University).

TABLE 6. APPROXIMATE DENSITY OF FEED AND BEDDING MATERIALS*

Material	Pounds Per Cubic Foot
Ear corn	28
Shelled corn	45
Ground corn	40
Oats	26
Ground oats	20
Soybean oil meal	45
Tankage	52
Alfalfa meal	35
Minerals	65-95
Straw, loose	4
Straw, baled	12
Shavings, baled	20
Shavings, loose	5

*Densities will vary approximately ±10 percent between various suppliers and method of storage.

TABLE 7. TYPICAL CORN-SOYBEAN OIL MEAL RATIONS FOR GROWING AND FINISHING SWINE

Ingredients	15 percent*	12 percent*
Ground yellow corn	79.15	86.50
Solvent SBOM (50 percent)	16.10	8.85
Calcium carbonate	0.80	0.80
Dicalcium phosphate	1.35	1.25
Iodized salt	0.50	0.50
Trace mineral mix (35-C-41)	0.10	0.10
Vitamin premix	2.00	2.00

*15 percent protein used for pigs from 50 to 120 lb and 12 percent from 120 lb to market weight. Ingredients on basis of weight.

Summary

1 Although research data is presented on the effects of physical environment on growth efficiency, many influences have not been established, particularly with reference to interactions of physical environment with physiology, nutrition, and disease.

2 More emphasis should be placed on better environment for the finishing hog in view of late research on improvement in performance which can be obtained.

3 Of the factors comprising physical environment, temperature control appears to be the most critical. Odor control becomes important primarily where low ventilation rates or summer cooling with mechanical refrigeration are used. Humidity seems to be of little concern unless accompanied by thermal stress. Light appears to have little or no effect on pork production.

4 Drafts have not yet been defined in terms of physical measurements. Alteration of air velocity, air temperature, or skin condition may eliminate drafts equally effectively. Since air motion is desirable to remove excess moisture and odor, and animals do not produce sufficient heat to adequately take care of the minimum ventilation rate during severe weather, use of the needed supplemental heat to warm the ventilating air may be a practical means of counteracting drafts.

5 Mechanical refrigeration for space control in hog production does not now appear to be feasible in view of adequacy of sprinklers or evaporative cooling. Evaporative coolers are limited to more arid regions, however, because of inadequate wet bulb depression in more humid climates. Zone cooling of lactating sows appears to hold promise since it minimizes the mechanical-refrigeration equipment and eliminates undesirable moisture accompanying spray or evaporative systems. However, zone cooling is still in the development stage.

6 With more emphasis on developing meat type hogs, environmental control is becoming increasingly important. This will mean a trend to enclosed confinement and more nearly complete artificial control, since too cold an environment contributes to poor efficiency and to producing fat and too warm an environment lowers daily gain.

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Confinement Housing of Swine

Components of a system combined for economy

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CONFINEMENT housing of swine is relatively new and a variety of terms have been developed to describe components of a system. The following terminology is used in this paper:

Farrowing House. A building or part of a building equipped for the care and protection of sows and baby pigs during the farrowing period and for three to eight weeks after farrowing.

Nursery. Quarters for the care of pigs after removal from the farrowing house and before moving to the finishing house. Sows may or may not be with the pigs during part of this period depending on weaning practices adopted.

Finishing Building. A building to house pigs from the time they weigh 40 to 50 lb until reaching market weight.

Farrow-to-finish Building. A building equipped for the farrowing of sows and for the care of pigs from birth to market weight in the same pen.

Housing Systems

References are made to several systems of housing. The one-building system obviously consists of a farrow-to-finish building. The two-building system utilizes a farrowing house and a finishing building. The three-building system utilizes a farrowing house, a nursery and a finishing building. The choice of a system is affected by many factors, the first of which is usually initial investment.

In this paper an attempt is made to evaluate the various systems in terms of first cost of building construction to see which combination of components will be most economical.

Building Scheduling

Fig. 1 is a graphical presentation of building scheduling for four farrowing systems. It is based on the assumption that hogs will be ready for market in a maximum of 24 weeks. It assumes that pigs will be moved to the finishing building at eight weeks of age whether it be a two-building or a three-building system. It assumes that the farrowing period will extend over a three-week period (the normal oestrus cycle of sows) and hence the total time to finish a group is 27 weeks. This three-week spread is represented by the diagonal lines of the graph.

For farrowing four times a year, a two-building system can be used. Pigs are kept in the farrowing house for eight weeks and then moved to the finishing building. This building must have capacity for two farrowing groups. The farrowing unit will be idle at least one week between each group and the finishing unit will be idle at least seven weeks between each group.

For farrowing six times a year, the scheduling gets more difficult. With good management and a generous amount of luck, the minimum building requirement would be a one-unit farrowing house, a one-unit nursery and a two-unit finishing building, or a two-unit farrowing house and a two-unit finishing building. Under this system, there would be one week of idle time between groups in both the farrowing house and the nursery. But with only two units in the finishing building, pigs in group three will be ready to enter at the same time as pigs in group one are ready to vacate. There is absolutely no idle time unless the first pigs of a group are held in the nursery longer. Graphically this would be represented by a vertical or nearly vertical line at the end of the nursery period. Another possibility is to provide extra pens in the finishing building, but not a complete third unit.

For farrowing eight times a year the schedule calls for a minimum of a one-unit farrowing house, a one-unit nursery and a three-unit finishing building. There is some overlapping in all three units, but as suggested above, some idle time could be created by holding the early pigs for a longer period in both the farrowing and nursery units. Some extra pens would be good insurance. Eight-times-a-year farrowing could be operated as two four-times-a-year units, but this would require a fourth finishing unit.

Twelve-times-a-year farrowing requires exactly twice as many farrowing, nursery and finishing units as does six-times-a-year farrowing and the same scheduling problem exists in the finishing unit. The only difference is that the problem catches up with one every four weeks instead of every eight weeks.

With a farrow-to-finish building there is no scheduling difficulty. For farrowing twice a year, one unit is required. For farrowing four times a year, two units are required, and so forth.

The foregoing building scheduling is subject to variations. Some possible variations have already been suggested. Another variation is to schedule the farrowings over 52 weeks instead of over 48 weeks plus four weeks vacation as suggested in the graph.

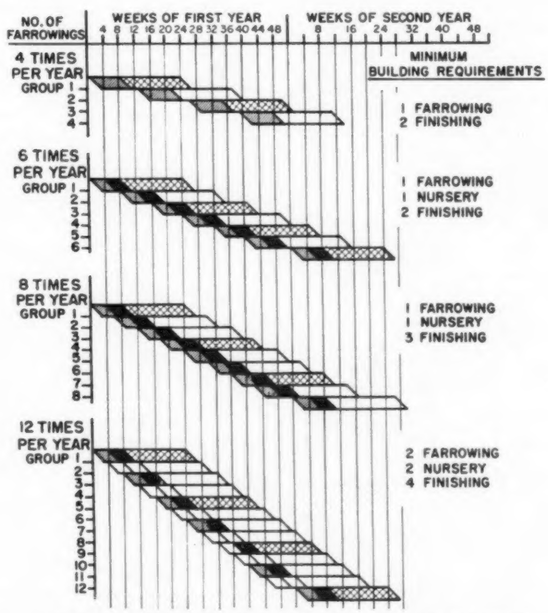
Cost Comparisons

With the building requirement established above, it is then possible to make some cost estimates and comparisons for the various systems. Prices stated are for central Illinois in 1960 and are based on the following assumptions:

(a) Contracted job

(b) New materials throughout

(c) Medium-priced equipment (feeders, waterers, farrowing stalls, etc.). Prices do not include manure-disposal equipment or automatic feed-processing and delivery equipment.



SHADED AREAS REPRESENT CYCLES FOR ONE SET OF BUILDINGS

Fig. 1 A graphical presentation of building scheduling for four farrowing systems of confinement swine raising

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(d) Minimum of grading

(e) Construction as recommended for the north central region of the United States.

Prices are for initial construction costs per pig capacity based on eight pigs per litter raised. Floor areas stated include allowances for wall thicknesses and alleyways.

Building	Price per pig
Farrowing house with stalls; sows fed on outside concrete lot: 50 sq ft per litter inside, 20 sq ft per litter outside	$31.00
Nursery building for four-week-old weaned pigs: 5 sq ft per pig all under roof	19.00
Finishing building with allowance of 12 sq ft per pig all under roof	37.00
Farrow-to-finish building with allowance of 12 sq ft per pig all under roof	47.00

To use the above cost figures in a comparison of systems, they must be further reduced to a figure that is the initial investment per pig per yearly pig capacity, as follows:

Farrow-to-finish

(two farrowings per year)

One farrow-to-finish unit	$47.00 ÷ 2 = $23.50

Four farrowings per year

One farrowing unit	$ 31.00
Two finishing units	74.00
	$105.00 ÷ 4 = $26.25

Six farrowings per year

One farrowing unit	$ 31.00
One nursery unit	19.00
Two finishing units	74.00
"Tail-enders" pens	15.00
	$139.00 ÷ 6 = $23.18

Eight farrowings per year

One farrowing unit	$31.00
One nursery unit	19.00
Three finishing units	111.00
"Tail-enders" pens	22.50
	$183.50 ÷ 8 = $22.94

Twelve farrowings per year

Two farrowing units	$ 62.00
Two nursery units	38.00
Four finishing units	148.00
"Tail-enders" pens	30.00
	$278.00 ÷ 12 = $23.18

With the exception of "four farrowings per year," costs of the other systems vary less than one dollar per pig. This certainly minimizes the importance of first cost.

Other Factors

It is known that by current standards a good environment can be provided for raising hogs under any of the housing systems referred to above. To say that one system is right and the others are wrong is not possible at this time. It does appear that factors other than first cost will influence housing decisions. The following are some of these:

- Management requirements
- "Stress" of the pigs
- More exacting requirement for environmental control
- Water and feed distribution
- Manure removal and disposal
- Disease-control requirements
- Type and location of old buildings available for use in the swine operation.

A close inspection of this list of factors reveals that first five items favor a farrow-to-finish building. And with the adoption of disease-free pig programs, the next to the last item above could also be handled in a farrow-to-finish building.

Management should be less difficult where building scheduling is not so critical. There should be less "stress" of the pigs if they are not moved. Environmental control should be more uniform in one building. Water and feed distribution and manure removal could be more easily designed and installed in several buildings that are exactly the same rather than in several buildings that are all different.

The author did not have a preconceived notion of showing preference for the farrow-to-finish building. To his knowledge, there are no research results available to prove the points made above, but if the cost estimates used are acceptable, then the statements concerning farrow-to-finish buildings are logical.

On the other hand, the last item listed above concerning old farm buildings available for remodeling might actually be the strongest factor. In fact, when the author was assigned this topic, he immediately thought of this recipe: Take one unused poultry laying house and convert it to a farrowing house. Then convert one old horse barn for a pig nursery. Blend with one new finishing building and add bred sows as needed to fill the facilities with healthy squealing pigs.

This recipe is one that is used many times. Why not just take the old horse barn and convert it to a farrow-to-finish building? It is probably too small for the desired total volume of pigs and it is likely to be too close to the farm home for satisfactory odor control. The same building can be used as a nursery because less odor is produced by four to eight-weeks-old pigs than from the same number of market hogs, and it will be tolerated by the farmer if a saving in building costs can be effected. Therefore, the two and three-building systems may remain popular.

Design

In this paper reference has been made to farrowing units, nursery units and finishing units. To suggest some uniformity in functional design, it is desirable to define a "unit".

A unit in hog production could be one sow and litter. It could be 100, 500, or 1,000 pigs to be marketed each year. It could be the number of pigs per finishing pen. A unit could be many numbers, but the number "eight" can be justified as follows:

Eight times one-half equals 4 — the number of sows and litters that can be grouped together in a nursery.

Eight times two equals 16 — the number of sows that can be serviced by a young boar.

Eight times three equals 24 — the number of sows that can be serviced by an older boar.

Eight times eight equals 64 — the number of pigs at eight pigs per litter that can be satisfactorily grouped together in one finishing pen.

Farrowing houses could be designed as 8-sow, 16-sow, 24-sow and 32-sow houses, and other buildings could be designed to accommodate the anticipated production of eight pigs per litter.

The author believes that the adoption of some standard unit of production will result in some building economy starting right at the drafting board and continuing through the manufacture of building components, ventilating systems, air-conditioning equipment, feeders and other items.

It is not the intent of this paper to present an "ideal" design of buildings and layout for a confinement swine-raising system. If such an "ideal" exists, it has not been recognized. There is one point that can be made that will help someone approach the ideal design. That point is that planning must begin with the design of a waste-disposal system. One of the reasons that hogs are being moved from pasture to confinement is to make feed distribution easier. Feed can be handled so readily in confinement that this part of the planning is not nearly as difficult as planning for efficient and sanitary manure handling.

Conclusion

There will be progress in swine management, nutrition and disease control. There will be improvements in environmental controls, building materials, feeding equipment and waste disposal. Engineers have a responsibility to be alert to new developments and to relate them to the design of systems and the design of individual buildings for confinement swine raising.

Apparent Densities of Dry Feed Ingredients

(Pounds per Cubic Foot)

ALFALFA PRODUCTS

Description	Weight/cu. ft.
*Alfalfa meal, dehydrated, 13%	16-18
*Alfalfa meal, dehydrated, 17%	18-22
*Alfalfa meal, suncured, 13%	14.0
*Alfalfa leaf meal	14.5
*Alfalfa stem meal	12.0
Alfalfa pellets, 13%	41-43
Alfalfa pellets, 17%	41-43
Alfalfa meal, fine ground	15-22
Alfalfa seed	48

ANIMAL PRODUCTS

Description	Weight/cu. ft.
*Blood meal	38.5
*Blood flour	30.0
*Meat meal	37.0
*Tankage (digester)	49¼
*Poultry by-product meal	34-37
Bone meal	50-53

BARLEY PRODUCTS

Description	Weight/cu. ft.
*Rolled barley	21-24
Barley (scoured)	41
Barley, whole	38-43
Barley, ground	24-26
Barley, malt	30-31

BREWERS PRODUCTS

Description	Weight/cu. ft.
*Brewers dried grains	14-15
*Malt sprouts	13-16

CITRUS PRODUCTS

Description	Weight/cu. ft.
Dried citrus pulp	20.5

CORN PRODUCTS

Description	Weight/cu. ft.
*Corn meal	38-40
*Corn bran	13
*Corn feed meal	33.5
*Corn chops (fine)	36-39
*Corn chops (medium)	38-42
*Corn chops (coarse)	40-44
*Corn grits (fine)	40-43
*Ear corn chops	35
*Corn gluten feed	26-33
*Corn gluten meal	32-43
*Hominy feed	25-28
*Corn oil meal	33-36
*Corn germ meal	35
Corn, ground	34-36b
Kibbled corn	20-22
Ear corn	56 (28)
Ground cobs	17
Pop corn, ear	56 (28)
Pop corn, shelled	44-45

COTTONSEED PRODUCTS

Description	Weight/cu. ft.
*Cottonseed oil meal	37-40
*Cottonseed cake	40-45
Cottonseed meats	40
Cottonseed cake, cracked	41
Cottonseed hulls	12
Cottonseed w/lint	18-25
Cottonseed, delinted	22-27

DISTILLERS PRODUCTS

Description	Weight/cu. ft.
*Corn distillers dried grains	18-19
*Corn distillers dried solubles	25-26

GRAIN SORGHUMS

Description	Weight/cu. ft.
Kafir	40-46
Sorghum seed	32-33
Kafir and milo	40-45
Milo, ground	32-36

LINSEED AND FLAX PRODUCTS

Description	Weight/cu. ft.
*Linseed oil cake	45-50
*Linseed oil meal (sol. ext.)	31-33
*Flaxseed screenings	26-28
*Linseed feed	20-21
Flaxseed	43-45

MARINE PRODUCTS

Description	Weight/cu. ft.
*Fish meal	30-34
*Shrimp meal	25

MILK PRODUCTS

Description	Weight/cu. ft.
*Dried whole whey	35-46
*Condensed buttermilk	31

MINERAL FEED

Description	Weight/cu. ft.
*Salt	62-70
*Calcium carbonate	75
*Defluorinated phosphate	97
Potassium iodide	22
Bentonite	51
Limestone	68
Phosphate	75
Sulphur	13
Cobalt sulphate	48
Copper sulphate	62
Ferrous carbonate	85-90
Phosphate, tricalcium	21
Zinc sulphate	85-88
Sodium bentonite	41

OAT PRODUCTS

Description	Weight/cu. ft.
*Oat hulls, unground	8-9
*Oat hulls, ground	11-12
*Oat middlings	38
*Oat chops	30
*Ground oats	20-25
*Pulverized oats	19-21
*Crushed oats	22
*Crimped oats	19-25
*Oat groats	46-47
*Feed oatmeal	16-32
Oats, whole	25-35
Oats, rolled	19-24

PEANUT PRODUCTS

Description	Weight/cu. ft.
Peanuts, unshelled	17-24
Peanuts, shelled	15-19

RICE PRODUCTS

Description	Weight/cu. ft.
*Rice bran	20-21
Polished rice	30
Rice hulls	20-21
Rice, hulled	45-49
Rice, grits	42-45
Rice, rough	32-36

RYE PRODUCTS

Description	Weight/cu. ft.
*Rye, bran	15-20
*Rye, feed	33
*Rye, middlings	42
Rye, shorts	32-33
Rye, whole	43-45

SCREENINGS

Description	Weight/cu. ft.
*Grain screenings	30
*Chaff and dust	20
*Dust	11

SOYBEAN PRODUCTS

Description	Weight/cu. ft.
*Ground soybeans	25-34
*Soybean millfeed	25-27
*Soybean hulls, unground	6-7
*Soybean hulls, ground	20
*Expeller soybean oil meal	36-40
*Sol. ext. soybean oil meal, 41%	34-36
*Sol. ext. soybean oil meal, 44%	35-38
*Sol. ext. soybean oil meal, 50%	41-42
Soybeans, whole	46-48
Soybeans, millfeed pellets	37-38

VITAMINS

Description	Weight/cu. ft.
Riboflavin	37
Vitamin A, dry	48

WHEAT PRODUCTS

Description	Weight/cu. ft.
*Wheat bran	11-16
*Wheat standard middlings	18-25
Wheat red dog	22-18
Wheat germ meal	28-32
Wheat, whole	45-52
Wheat screenings	17-25
Wheat, ground	38-39
Wheat, coarse cracked	35-38
Wheat, flakes	31-33

YEAST

Description	Weight/cu. ft.
*Dried yeast	41

MISCELLANEOUS PRODUCTS

Description	Weight/cu. ft.
*Buckwheat middlings	22
*Dried beet pulp	11-16
*Copra oil meal	27
*Copra oil cake	23
Buckwheat bran	15-16
Buckwheat hulls	12-13
Buckwheat, whole	37-42
Beets	48
Broom corn seed	41-42
Malt, wet	60-65
Malt meal	36-40
Malt, dry	27-32
Brewers grains, wet	55-60
Clover seed	48
Corn and oats chops	17-18
Feeds:	
Dairy, light	18-22
Dairy, heavy	20-28
Dairy, concentrate	43
Hay, loose	5
Hay, pressed	8
Millet	38-40
Molasses feed	20-25
Pellets:	
¼″ hog pellets	39
⅜″ rabbit pellets	37
Peas, dried	48-50
Sugar	54-56
Sea coll	65
Stilbestrol	40
Sunflower seed	26-38
Timothy seed	36
Urea	34-42

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*Items listed by the Association of American Feed Control Officials.

DAIRY

Helter-Skelter Dairying

Adjusting production to the dairy cow's needs

W. W. Snyder

THE topic of helter-skelter dairying was selected for this conference in order to call attention to some of the problems confronting the average Midwest dairyman, especially those related to expanding the herd size as a means of keeping up with economic pressures. This increase in herd size has created problems in management, feeding and milking that should be considered. No attempt will be made to discuss the operation of the large herds (200 cows or more), because the problems in these herds are entirely different.

Perhaps a question would suggest the real purpose of this topic. Are we as a group, the dairy specialist, the engineer, the economist, the manufacturer of dairy equipment, and others promoting helter-skelter milking, which in turn lowers the average milk production per cow, increases herd wastage, and also reduces the milk quality? If this is the case, we are not helping the dairy industry, the dairy farmer, nor the consumer of dairy products.

Too often those of us advising the average dairyman try to solve his economic problems by suggesting an increase in cow numbers to a specific herd size. We try to calculate the maximum number of cows one man can handle or the number of cows one man can milk in a specified time with one system as compared with another. When we think in terms of cow numbers only, we are inclined to forget the importance of the individual cow in the herd. We must remember that *each* cow in the herd is important as an individual and should return a profit to her owner in a balanced dairy farm operation.

Most certainly we must use cow numbers, space per cow, cows per hour and similar units when planning dairy farm structures, but we should also include pounds of milk and net returns. I do not intend to condemn the engineer who designs dairy barns nor the reports of research workers in the area of dairy cattle housing, but I do hope to emphasize the need for more research involving the team approach. We need more research studies dealing with the normal behavior of the individual dairy cow including all aspects of feeding, breeding, management and disease control. It should be understood that milking is included as a part of herd management. Perhaps the agricultural engineer, the dairyman, the economist, the physiologist, the chemist and others could combine their efforts to study the cow and her behavior when in herds of various sizes and under numerous systems of management. Of course, we have some data, but are the facts complete and have we included all the essential factors in our values for long-term net returns?

There is another important factor that must be considered when dealing with this topic of helter-skelter dairying and that is the herd operator. Certainly he is responsible for the good or poor results obtained. The outstanding operator will obtain good results with nearly any system while the poor man needs the very best system to obtain even fair results. The operator holds the key to success or failure in the dairy business and you as engineers cannot design a foolproof system for the poor man. The engineer should, however, design the system so that the average man can obtain good results, and we assume this is being done in most cases. The important fact is this: both the man and the individual cow should be considered when evaluating research findings or when designing a system for a specific dairy farm. I trust we have properly evaluated the importance of both the cow and the man in our research reports.

Perhaps some of you expected me to deal with such general topics as breeding, nutrition, disease control, sanitation and marketing problems. Yes, these topics are all very important to us, and probably the other speakers on this program will point out some important research in several of these areas as related to our problems. We are all interested in developing plans for dairy farm buildings that will enable the dairyman to increase his long-term net income. This implies efficient and profitable production of high-quality milk, the kind of milk that everyone will want to drink. To accomplish this, the dairyman must have good cows, cows with the genetic capacity for high production and efficient production. He must feed, manage, house, and care for the entire herd so that each cow will produce milk at a profit for the herd owner. Helter-skelter dairying may yield fair to good results for a short time but the long-term net income may not be high enough to give the dairyman the standard of living he should expect.

Standards for a Balanced Program

Those of us working with dairymen as specialists in our respective fields should have practical and reasonable standards which can be used as bench marks to guide us in designing building plans in line with the entire farm operation. Recently the team approach was used to arrive at such standards for Michigan dairymen. Specialists in dairy, agricultural engineering, and agricultural economics along with county agents studied *all* available records for many dairy farms in twelve Michigan counties. After studying the records for those dairy farms that were making money and comparing them with those that were just breaking even, specific standards were suggested. These standards were reported by John A. Speicher in *Hoard's Dairyman,* March 25, 1960, and were indicated as practical and attainable for Michigan dairymen. They may be of value to engineers:

STANDARDS FOR MICHIGAN DAIRYMEN

Tillable acres per man	120-140 acres
Number of cows per man	25-30 cows
Crop value per acre per year	$55.00
Fertilizer used per acre per year	$6 to $10
Milk produced per acre per year	2300 lb
Milk produced per man per year	275,000 lb
Gross income per acre per year	$100
Gross income per $1,000 invested in machinery	$2,000
Gross income per man per year	$12,000
Pounds of milk per cow – Holstein	11,000 lb
Ayrshire – Brown Swiss	10,000 lb
Guernsey	8,800 lb
Jersey	7,700 lb

Crop yields, milk production, and the balanced size of operation are the critical points, and when combined with per cow, per man and per acre capabilities, we have a rather complete picture of the whole farm operation. We should have a balanced farm operation.

These standards are for a balanced dairy farming program for the man who is a full-time dairyman under Michigan conditions. Note that the herd size is 25 to 30 cows. With this herd size, the level of milk production indicated for each breed could be maintained and thus 25 Holstein cows should produce the 275,000 lb of milk per year. Standards can be used as a guide in planning buildings and facilities if all the facts are considered. The above-noted standards indicate that four acres of tillable land are required to produce the feed for a cow and her replacement for a year. The engineer, in planning the farm structures, should provide space for all the cattle plus space for the feed and bedding, and also, when considering the handling of materials, he should try to maximize the use of available equipment. When the conditions of dairy farming vary from these Michigan conditions, then most certainly the standards should be adjusted for the new conditions.

If we design a system which is not geared to the entire operation, the net returns may not be in balance. The dairyman cannot

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expand his operation without increasing his total investment, and if he doubles the herd size, his investment may be so large that the equipment will be worn out or obsolete before it is paid for. L. H. Brown and R. G. Wheeler cautioned against overexpansion in two articles in a publication, "Michigan Farm Economics," February, 1959. Brown concluded that, if the farm business is now in balance at 20 to 30 cows and the dairyman starts to increase a few cows in herd size, he likely may not find a point of balance short of 60 to 80 cows. Wheeler used two actual farms that were in balance, one with a 20-cow herd and the other with a 30-cow herd, and then carefully budgeted all possible investments needed to expand the herd size to 50, 80 and 120 cows. His calculations indicated that the point of balance was the 80 or 120 cow herd. Expanding to the 50-cow herd was not profitable for either of these farms since the investments for the plan could not be repaid from the added earnings.

We have had some experience with unwise expansion of the dairy herd by fairly good managers who were unable to pay off their indebtedness. The helter-skelter expansion costs ate up the profits. Of course, every one connected with the extension service was blamed for the failure.

We should not imply that the dairyman must have exactly 25 or 30 dairy cows on a farm of exactly 120 to 140 acres, nor should we indicate that the 50 or 60-cow herd is always unprofitable. We must remember that in areas where all of the concentrates are purchased, the number of cows per man may average 40 cows or more, and if all the feed is purchased, this average may be 60 cows or more per man. Thus we need plans for herds of various sizes.

We do notice an increase in the number of dairy herds of 100 cows or more in some sections of the country. We could cite several successful partnership arrangements in Michigan consisting of three close relatives, such as three brothers operating balanced, practical and profitable dairy farm with herds of 90 to 100 cows. This may be a trend, and there are some definite advantages as well as disadvantages for this size of operation aside from the economical aspects. The feeding, milking and entire operation of the 100-cow herd requires good management to realize a good income.

Feeding the Dairy Herd

Aside from feeding a balanced ration, we should provide good cows with the opportunity to eat all the roughage they can consume. The amount of concentrates should be based upon the individual cow's needs, especially her milk production. In loose-housing systems, the feeding of roughages has not always been given the attention it should receive. In some cases, we have attempted to reduce the feed bunk space or the feeding space per cow for both hay and silage to an absolute minimum in a system of self-feeding of both roughages. The dairyman may also neglect to clean these feeding areas as often as he should. The net result is that the more timid cows in the herd, the cows in the lower half of the social order, will not have an opportunity to eat the forage they need for a high-level, economical milk production. This need not be the case and I sincerely believe that if we have a well-designed loose-housing system and then properly manage the entire operation, we can obtain maximum milk production.

Let us consider the feeding and forage-handling systems. Have we been thinking too much in terms of self-feeding and minimum handling of the forage and not enough in terms of maximum roughage consumption? Could we incorporate the minimum manual handling of bulky roughages with a system of frequently feeding these forages during the day so the cows will have some clean fresh feed available at all times? We must also remember that silages and fresh green feeds should not be fed for a period of at least two hours prior to milking because of the undesirable feed flavor in the milk when silage, pasture, and some hays are fed just prior to milking.

There are several factors that should be considered with this possibility of frequent feeding of forages. Perhaps we could design the system so that the same feed bunk could be utilized for most of the forages. If we did this, we could provide feed bunk space in excess of the minimum of two feet per cow usually recommended to insure all cows sufficient space to eat. Perhaps we could also take better advantage of the difference in the quality of hay usually available on most of our midwest dairy farms. Many present-day systems provide a feed bunk for silage and, in addition, a feeding area along the hay barn for the hay. Thus, when we have one cutting of good hay and another of poor quality, the milk production for the herd will be lower when the cows are forced to eat the poor hay.

The Michigan dairymen with the highest producing herds in stanchion barns take advantage of the frequent feeding of roughages. In several outstanding herds, roughages are fed four to five times per day. In one of the best-managed herds in the state, hay is fed four times and silage twice per day. This dairyman utilizes some poor quality hay in two light feedings and of course he has mostly excellent hay. Above all, he follows a regular and excellent routine in his feeding. Perhaps this may not be entirely practical in loose-housing barns but certainly some effort should be made to move in this direction. Perhaps we can improve the present system.

Feeding Concentrates

The feeding of concentrates may be a problem in some herds and should be mentioned. In loose housing, the feeding of concentrates is usually combined with the milking operation. In some cases, the high-producing cows are not allowed sufficient time to eat the amount of concentrates they need for maximum milk production while the low producers may eat more than is economical. The total amount, or the average amount, consumed by the herd may be reasonable but each cow may not have been fed according to her needs.

The time allowed to eat concentrates is determined by the time the cows are in the milking room. Research reports indicate that the rate of eating ground feed will depend upon the fineness of the grind and also other factors such as the moisture content of the feed. Of course, cows can be trained to eat at a faster rate but this should not be carried too far. By adding water to the concentrate mix in sufficient amounts, the time required to eat the mix can be reduced. Perhaps we should include these ideas in our plans for milking rooms in the future or at least provide the cow with the opportunity to eat the concentrates she needs. Perhaps pellets could be used.

Milking the Dairy Herd

Since the milking operation requires more total time than any other dairy farm chore, it is logical that we should have many research studies dealing with milking time. The dairyman is interested in reducing this chore time and numerous reports have appeared within the last few years indicating very fast milking rates.

Since the introduction of the herringbone milking system into the United States, we have seen claims for one man milking up to 60 cows per hour and averages of 50 cows per man per hour. Should we place more emphasis upon speed of milking, or helter-skelter milking, than we do upon good milking? Even though I have had a small part in time and motion studies involving the herringbone system, I cannot condone stopwatch milking just for the sake of speed. We should all be interested in good milking rather than helter-skelter milking.

What is good milking? Good milking is managed milking and it may be fast or slow, depending upon the individual cows in the herd and the system used. Yes, managed so that we can take advantage of the milking rate for each cow and do a complete job of milking. Cows vary in the time required to milk them, and if we do not milk each cow as an individual, we will not do the best job of milking.

Let us consider the most significant problem of helter-skelter milking: mastitis. The mastitis problem is serious and in spite of the large quantities of antibiotic used by dairymen, we appear to have just as much mastitis today as we did 20 years ago. Mastitis not only reduces milk production and milk quality but also increases herd wastage.

Perhaps we should use a new approach in our fight against mastitis. Why not consider good milking practices?

There are two concepts for the causes of mastitis as follows:

(a) One concept recognizes predisposing causes, but the major emphasis is placed upon specific microorganisms as direct causes of the disease. Elimination of specific organisms from the udder and its environment is emphasized in control programs based upon this concept.

(b) Another concept holds that mastitis occurs when predisposing causes, such as poor milking procedures or injury to the udder, reduce the resistance of the cow and allows the organisms present in the udder to cause the disease.

The major difference between these concepts is the emphasis placed on predisposing factors and microorganisms. The one suggests that we fight "bugs"; the other suggests we fight poor milking practices.

Recently a milking-machine manufacturer published a booklet on mastitis. The author listed thirty-one items as a partial list of the things that have been blamed for causing mastitis. Following the list, he stated that some of the things mentioned could cause mastitis but few of them are factors. He added: "We are sure that improper installation and careless use of mechanical milkers causes more injuries by far than any other five things you can name—because careless milking is something that can happen every day."

Let me suggest that too often the milking machine is the most neglected piece of equipment on the farm today. Also, the dairyman is too apt to choose the easy way out by "chasing bugs" with antibiotics rather than correct the real cause of the mastitis trouble. Should we consider the possibility of improving our milking machines?

The reports in *Hoard's Dairyman* dealing with the mastitis control program in California have renewed our efforts to fight mastitis. The four articles appeared March 10, March 25, April 10 and April 25, 1959. The program was based upon a team approach to solve the problem. The major emphasis was placed on the proper use of the milking machines. The strain gage amplifier and recorder was suggested as a possible tool to check the operation of milking machines. Another factor stressed in these reports was the use of the small-bore teat-cup liners.

The important point for us to consider here is the fact that many dairymen are not following good milking practices, in some cases due to faulty or undesirable equipment and in other cases due to the poor operation of the equipment.

In order to improve milking practices, we should consider the five essential parts of the modern vacuum milking machine. This machine is the pulsating type using the double-chambered teat-cup assembly with an inner rubber liner and an outer shell to form the double chamber. The five essential parts of the milking machine are as follows: vacuum pump and power to operate the pump, vacuum line, vacuum regulator or controller, pulsator, and teat-cup claw assembly. These five parts must be combined to form a unit and each part has a specific function to perform. Unless the entire installation is working properly, we cannot expect a first-class job of milking even with a good operator. This point need not be emphasized for the engineer; however, the milking-machine operator may not always understand the importance of the entire system.

In recent years, some milking machines have appeared on the market which are designed to operate at a "so-called" low-vacuum level of 10 in. of mercury. For others, the recommended vacuum level is 12 to 15 in. Are either of these vacuum levels correct for the most effective job of milking? Some British workers suggest that perhaps 15 to 18 in. of mercury may be more satisfactory. This is only a suggestion and based upon their milking-rate studies. How about the pulsation rate? Should we have adjustable pulsations? What about the drop-off milkers? Are the small-bore liners as good as claims indicate? Do we need more research studies dealing with all phases of machine milking? If we do, I would suggest the team approach, because certainly the physiological response of the cow is all important in machine milking.

Before closing this discussion, some milking rates for high-producing herds should be considered. The milking time for 737 Michigan DHIA herds may be of interest. These are unpublished data used by R. C. Knisely for his master's thesis.

This study indicated that 80.6 percent of the herds were housed in stanchion barns, and for these herds the average milking rate was 13.7 cows per man-hour. For all the loose housing barns, 17.5 cows were milked per man-hour, but when the cows were milked in a milking room with a pipeline to carry the milk, the rate was increased to 20.4 cows per man-hour.

This relatively slow rate of milking is of interest to me since these are the best herds in Michigan. Last year our DHIA herd average was the third highest in the United States, being exceeded only by California and Utah. I do not suggest that these dairymen are all doing an excellent job of milking and that they cannot improve their procedures, but they are profitable operations.

From other studies, I would conclude that the milking rate can be increased up to 30 or 35 cows per man-hour and still do a good job of milking if the milking system is well planned. This is based on using no more than four machines in a double-four herringbone or three machines in arrangements such as the double-three walk-through system. I am also assuming that to do a good job of complete milking, the man should not be expected to milk at a rate in excess of 80 percent of the possible maximum milking rate. I am well aware of studies which indicate average milking rates of 40 to 45 cows for some milking systems.

In conclusion, we should emphasize the need for more research reports such as the British publication, Bulletin No. 177, "Machine Milking," published by the Ministry of Agriculture, Fisheries and Food, London, because eight staff members of the National Institute for Research in Dairying cooperated in preparing the manuscript. When such procedures are followed, we are more likely to base our ideas on sound facts. The dairy cow is a well-developed, high milk-producing, habit-forming, physiological creature requiring an expert to understand her needs, likes and dislikes. She thrives on regularity and dislikes helter-skelter operations.

Physical Environment and Confinement Housing of Dairy Cows

Robert E. Stewart
Member ASAE

IN its broadest sense, the term "environment" is too all-inclusive for convenient use by the engineer of animal shelters. The term "physical environment" is somewhat more restricted, but is still too unwieldy for a short paper. Therefore, in this paper "physical environment" is arbitrarily defined to include only temperature and humidity within the confinement space.

Milk Production

Fig. 1 shows that temperatures of 40 F or below may cause milk production losses, depending on the breed. Under confinement housing conditions it is doubtful that temperatures much below 40 F would be tolerated by the operator if a stall barn system is used. If a loose-housing system is used, winter temperatures are usually moderated by the fermentation heat of the manure pack, and milking would be done in the warm milking barn. Therefore, it appears that the production loss at high temperature is far more important than that at low temperature.

Referring again to Fig. 1, it will be noted that, when cows are exposed to constant temperatures of about 75 F or above, increasingly severe loss in milk production occurs with rising temperature. This indicates that the basic problem in summer confinement housing may be how to provide some economic means of moderating the temperature when it rises above 75 F. Under loose-housing conditions with open-front structures, protection from solar radiation and maximum utilization of natural air movement represent the limit of environmental modification. With closed structures, however, air conditioning can possibly be used to advantage if herd size and production potential are sufficiently large to justify it.

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Relative humidity has little effect on production at temperatures between 17 and 75 F (1)*. At temperatures above 75 F, increasing relative humidity generally causes loss in production. For example, at 85 F, 44 percent relative humidity caused a 3 percent production loss in Holsteins, while 90 percent relative humidity caused a 31 percent loss at the same temperature (1). Similar production losses have been shown in other breeds, indicating that humidity is a definite problem at temperatures above 75 F. The humidity problem is somewhat irrelevant in open structures, but can become acute in closed structures. Humidity can be controlled in closed structures by means of either ventilation or air conditioning, or both.

The U. S. Weather Bureau "discomfort index" may offer the shelter designer a convenient method for considering the effects of temperature and relative humidity taken together. The discomfort index (DI) is defined as

$$DI = 0.55T_{db} + (0.2T_{dp} + 17.5)$$

where

T_{db} = dry-bulb temperature, deg F

and

T_{dp} = dew-point temperature, deg F.

In recent controlled experiments at the Missouri Climatic Laboratory, Cargill (2) has attempted to relate the DI to milk production in the temperature range from 65 to 90 F, the temperature range of principal interest to designers of dairy barn air conditioning. This attempt has resulted in Fig. 3 which relates deviation from normal production to the discomfort index. Within the specified temperature range, Fig. 3 indicates that rising humidity at a given temperature causes significant production loss in Holsteins. Fig. 3 further indicates that the designer should attempt to hold the DI to about 75 or less for top performance in closed shelters.

To sum up, research and other kinds of experience have shown that dairy cows have best production at temperatures between about 45 and 65 F and that relative humidity effects on production are insignificant within this temperature range, but are significant at higher temperatures.

Heat and Moisture

Fig. 2 shows heat and moisture dissipation from dairy cows as related to temperature within confinement space. The curves are considered to be applicable to cows in stanchions under typical barn conditions, but with no allowance for heat from lights and other equipment or for heat emitted by people within the space. The moisture curve includes moisture evaporated from stall, gutter and manger surfaces, i.e., the moisture which would be handled by a ventilation system. The curves apply to both Jersey and Holstein breeds although the values for Jerseys may be slightly low (5 to 10 percent) per unit body weight. The rates indicated in the curves were measured

*Numbers in parentheses refer to the appended references.

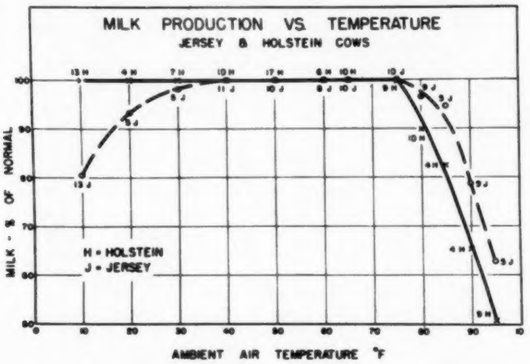

Fig. 1 Percent of normal milk production at various environmental temperatures. The relative humidity ranged from 55 to 70 percent. Slightly modified from reference (1), climatic laboratory, University of Missouri

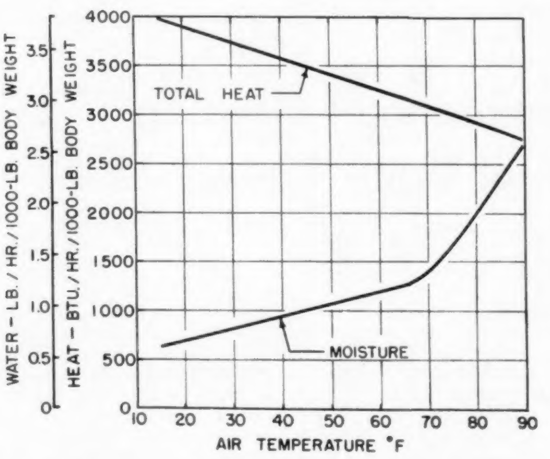

Fig. 2 Heat and moisture dissipation rates by stanchioned dairy cows, including moisture evaporated from stall surfaces not including heat from lights, men or equipment. Data were taken at 55 to 70 percent relative humidity, except the 90 F points. Slightly modified from reference (1), climatic laboratory, University of Missouri

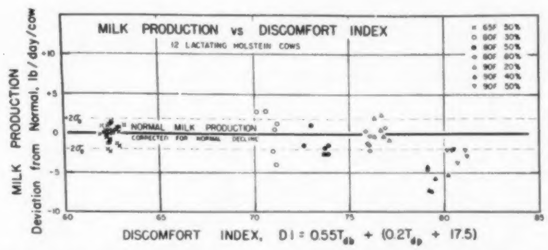

Fig. 3 Milk production of Holstein cows as related to the U.S. Weather Bureau discomfort index. The raw data on production were made available by courtesy of the department of dairy husbandry, University of Missouri. From Cargill (2), climatic laboratory, University of Missouri

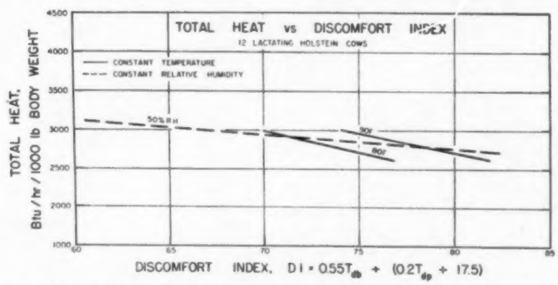

Fig. 4 Total heat of Holstein cows as related to discomfort index. Total heat is the sum of sensible plus latent heat. These curves are modified from Cargill (2), climatic laboratory, University of Missouri

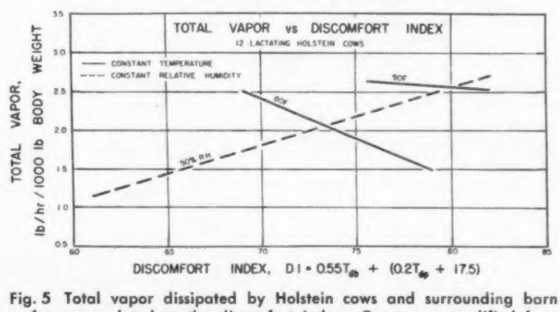

Fig. 5 Total vapor dissipated by Holstein cows and surrounding barn surfaces as related to the discomfort index. Curves are modified from Cargill (2), climatic laboratory, University of Missouri

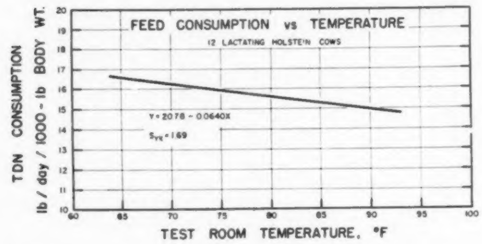

Fig. 6 Feed consumption of Holstein cows in relation to environmental temperature. The raw data for feed consumption are by courtesy of the department of dairy husbandry, University of Missouri. From Cargill (2), climatic laboratory, University of Missouri

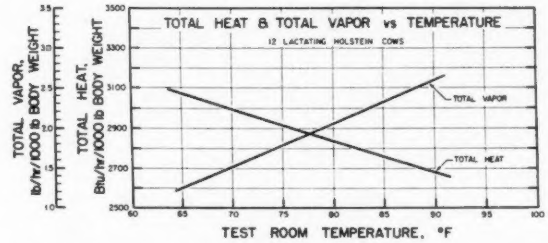

Fig. 7 Total heat and moisture dissipated by Holstein cows under barn conditions, as function of environmental temperature. The data are pooled for relative humidities ranging from 20 to 80 percent. (Vapor curve not to be read against the heat scale.) Adapted from Cargill (2), climatic laboratory, University of Missouri

at relative humidities ranging from about 55 to 70 percent except for the 90 F data, which were obtained at relative humidities ranging from 20 to 50 percent.

For comparative reasons the moisture curve in Fig. 2 is referred to both water and heat scales with the latent heat of vaporization assumed to be 1044 Btu per pound. By this means the percentage of total heat formed by the moisture fraction may be easily determined at any temperature. Likewise, the conversion of moisture to heat is done automatically by this type of arrangement. It is interesting to observe that late work in the 80 - 90 F air-temperature range indicates that total heat dissipation is nearly 100 percent in the vapor state at 90 F.

The curves in Fig. 2 may be used to best advantage in design of ventilation systems under cold conditions whereby a proper balance between air flow for temperature control and air flow for moisture control is desired.

It was mentioned above that the information conveyed by Fig. 3 suggests a limiting discomfort index of 75. Using this DI value of 75, the curves of Figs. 4 and 5 can be entered for more detailed heat and moisture data than were previously available. Fig. 4 (2) offers the designer a means of taking account of both temperature and humidity in applications involving *air conditioning*. The figure should be entered with a value of DI selected from the probability relation of Fig. 3. If 80 F is the assumed inside temperature, a corresponding value of dew-point temperature can be calculated from the equation for discomfort index. The total heat production for design purposes would be determined from the intersection of the selected DI value (probably 75) and the curve for 80 F. A similar approach can be used if the designer selects a limiting relative humidity of 50 percent with a DI of, say 75. This corresponds to a dry-bulb temperature of about 82 F; slightly more heat dissipation is encountered under these conditions, although the comfort situation is considered to be the same.

Fig. 5 (2) can be used in the same way as outlined above for Fig. 4, if values for total vapor dissipation are desired as a function of the discomfort index. Note that total vapor dissipation means the sum of vapor from the animals and the surrounding barn surfaces. Total vapor, therefore, is that vapor dissipation which would necessarily be handled by a ventilating or air-conditioning system.

Feed Consumption

Fig. 6 (2) shows the relation between TDN consumption and environmental temperature for the temperature range of greatest interest in the cow comfort problem. The data were taken with Holstein cows, but for estimation purposes can also be used for other breeds. Since the feed consumption has been converted to TDN, the curve can be applied to hay, grain and silage by appropriate reconversion.

Air Conditioning

The air-conditioning process has been emphasized because it is rarely used at present, its value is generally discounted or misunderstood, and the design factors are not commonly available in the literature. Yet the physiological nature of the dairy cow is such that her favorable response to cooling when temperatures are high may prove to be of the highest economic importance. Some details of the design factors were given in a previous paper (3).

The latest work on heat and moisture dissipation in the air-conditioning range from 65 to 90 F is presented in Fig. 7 (2). These curves are more detailed than are those of Fig. 2, hence perhaps more useful for close estimation of the heat loads which would be encountered. The data apply to Holstein cows only, but are considered typical of the large breeds. Note that the curves of Fig. 7 are not referred to a common heat base; total vapor values should be taken only from the vapor scale. The data are pooled for relative humidities ranging from 20 to 80 percent. Conservative design of dairy barn air-conditioning systems would probably include two assumptions: *(a)* about 20 to 30 cfm per cow of incoming fresh air will be handled, and *(b)* the refrigerating devices must process the *total heat* output of the animals, whether in latent or sensible form. In addition, adequate filtration of the recirculated air must be provided.

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2 Cargill, B. F. Unpublished Ph.D. thesis, University of Missouri.

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Confinement Housing of Dairy Cows

S. A. Witzel
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FOR purposes of definition of confinement housing for dairy cows as used in this paper, it is assumed that three conditions would be satisfied: *(a)* there would be zero pasture, or nearly so, *(b)* all roughages would be fed the year round, and *(c)* uniform management practices would, for the most part, be followed throughout all seasons of the year.

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Confinement housing presents a new concept for dairy-cow housing in the midwest region that is changing long-established practices. Mechanical harvesting has proven superior to grazing in terms of yields per acre. Herd size is no longer limited by farm size. Uniform year-round operation can be maintained. Better controls simplify the practice of good herd management, since operational practices are essentially the same in all seasons. This permits a simplified arrangement, more complete mechanization, and the adoption of refinements in opera-

tional practices which improve labor efficiency, maintain a high level of production, and reduce operating costs per unit of production. Herd management also benefits, since the risk of losses from bloat, change in feeds, excessive exercise, short pasture, and like hazards may be minimized or eliminated.

Confinement housing for dairy cows is proving practical and profitable in many areas. The methods involved tend to increase herd size, improve labor efficiency, attract better help, and result in more efficient use of buildings, yards, and equipment. Greater specialization and a well-established operation producing a substantial amount of uniformly high-quality milk have advantages in marketing and in attracting the necessary financing and qualified management.

Success in any type of dairy operation depends upon high milk production efficiency; and the factors which have a major effect in this area include efficient housing, high quality feeds and roughages, and good herd management. Dr. E. L. Corley* has shown that the level of production maintained by a cow is due to breeding for high production and all environmental factors in the ratio of approximately 30 to 70. Special emphasis should, therefore, be placed on environmental factors, including good herd health, and a long productive-cow life for profitable dairying.

Dairymen must win and hold their markets, and this means that every effort should be made to produce a wholesome product at all times, maintaining the dairy enterprise in full conformity with local regulations and keeping it inviting to consumer observation. After all, other foods are always competing with dairy products for the consumer's dollar. Engineers and dairymen should plan the farm dairy facility with major emphasis on the premise that the product to be produced is a human food, any of it being subject to formulation for the newborn infant. Quality of product should outweigh any tempting short cuts that might impair it.

*E. L. Corley, "Environmental Influences on the Production of Dairy Cattle," Wisconsin Agricultural Experiment Station, farm and home week, February, 1960 (mimeograph).

Dairy Housing in Region

There are currently many conventional stall barns in which milk is produced and many of these need improvements. Stalls are often too short and too narrow, and the arrangement may prevent efficient operation. High-quality milk is produced by some operators in stall barns, but in others the quality is being impaired, as was found in a survey conducted on ten dairy farms with stall barns in the Madison area this past winter. All of the milk met grade A standards, due in part to good bulk milk cooling tanks. However, milking time observation, photographs of cows at milking time, and substantially complete laboratory tests on the milk provided evidence which agreed on one point, namely, that some producers were consistently producing better quality milk than others. One operator had reduced milking time to the simple operation of

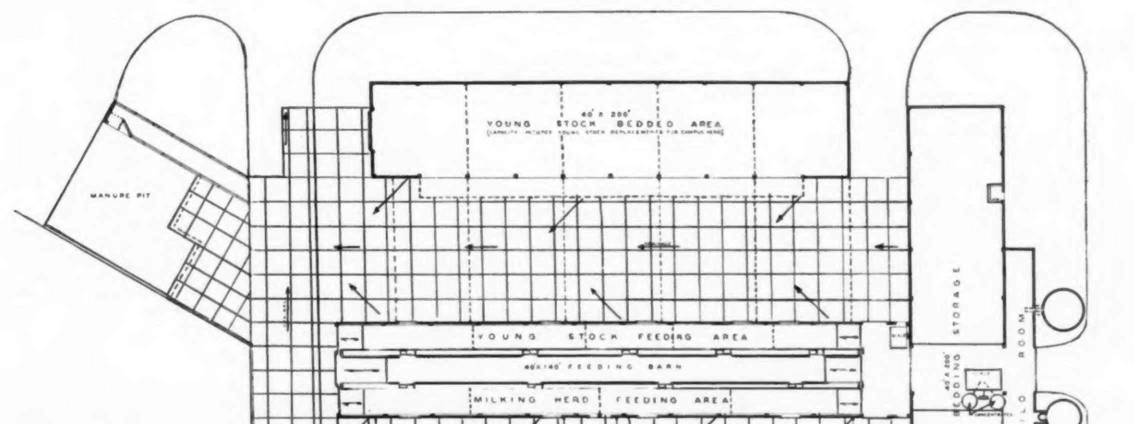


Fig. 1 Plan of university farm dairy unit

putting milkers on and taking them off. All other steps to good managed milking practice had been eliminated. The study pointed to the need for milking time inspection. To the engineer the study tended to emphasize the need for a better place to milk the cows especially when the herd is large and the operator is hurried.

The farm milking plant makes good milking much easier to perform, provided it is a well-planned and fully-equipped facility. It is a popular conception that milking plants and loose housing are one and the same. However, many operators with large stall barn units are interested in the advantages of farm milking plants. As herd size increases and operators get older, the stooping and bending is harder. Also, a cleaner, safer place to milk may attract help that would otherwise not be available. It is possible to find farm milking plants that are designed far beyond the ability of the operator to keep up with his equipment. Here again, when hurried, the operator tends to cut corners necessary in carrying out good managed milking practices. Managed milking requires washed and clean udders, wiped dry with a sanitary individual towel, regular use of strip cup, and enough machine strip operation to be sure that all four quarters are milked out before the machine is removed. Both udder and teat cups are to be sanitized before each cow is milked.

As a general rule in our state and up to this time, the stall barn seems to be most popular for herds under 50 to 60 cows, while loose housing is more popular for herds of more than 50 to 60 cows. There are several exceptions with stall barns to 156 cows and numerous loose-housing systems for herds as small as 30 cows. The comparative high cost of a minimum size of farm milking plant may increase the cost per cow for housing of smaller herds enough to offset the advantages. Similarly, the total housing cost for herds of 100 cows may run 25 to 35 percent less per cow than for herds of 40 to 60 cows when a farm milking plant is included.

The efficiency of dairy cow housing for the nation as a whole can be markedly improved. Some dairy herds are still handled as inefficiently as they were 50 years ago, using perhaps 150 man-hours per cow per year. There are other dairy farms where the annual labor requirement per cow falls between 60 and 70 man-hours per cow per year. For the national average a 30 percent reduction in labor per 100 lb of milk is shown. While not as spectacular as the mechanization of some farm crops, progress is being made. Farm buildings require a little more time to wear out than farm machinery. However, there is ample opportunity for labor saving in the production of milk before all dairy farms measure up to the better practices as we know them today. No doubt there is ample opportunity for new labor-saving improvements in the best systems in present operation.

In comparing loose housing with stall barns, mechanization for the latter becomes more difficult and costly as refinements and more complete mechanization are adopted. Cows confined to stalls cannot help themselves, select the feed they want, go out for sunshine, or obtain exercise without the dairyman being on hand to wait on them. This means more man hours of labor per unit of product.

Stall Barn Housing

Stall barn housing can be made more efficient than many such barns now are. As herd sizes increase, one soon realizes that the 20 tons of milk, feed, bedding, and manure that must be handled per cow per year—and often more than once — offer ample opportunity for materials-handling equipment. Consider the silo unloaders with power-operated silage carts, chopper wagons, or conveyors to feed silage; bulk bin and power-operated cart or conveyor for feeding the grain-concentrate mix; the CIP (cleaned-in-place) pipeline milker for transport of milk to bulk tank; the mechanical barn cleaner and tractor with loader and scraper for pen, young stock resting area, and yard cleaning; automatically controlled ventilation and individual watering devices. Several other operations associated with stall-barn housing such as hay feeding, manger cleaning, bedding, liming, tying, and untying cows have not fully responded to attempts at mechanization at this time.

By providing some duplicate facilities required in a stall barn, yard feeding for the herd in stall barns may be an alternate to barn feeding. In yard feeding cows can select the roughages they prefer and can obtain exercise, sunshine, and fresh air; the hay-feeding problem may be minimized by feeding directly from storage. The cows may be taken into the milking room directly from the paved barn lot. For successful operation, stall barn cows turned out for the day or night, if in shifts, will need a building for shelter and wind protection in the barnyard and a paved lot that is kept in clean condition except when frozen. Here yard feeding facilities would be much the same as for loose housing. Owners of stall barns may find this to be one step in converting to loose housing. Where bedding is very scarce or expensive, the stall barn does afford a resting place for the herd with minimum bedding use.

When cows are rotated between the stall barn for resting and the barn yard for feeding, each for approximately one-half of the day, it is important that the stall barn be thoroughly ventilated and that the temperature be allowed to drop to the 40 or 45-deg mark in colder parts of the winter. Operated in this way, bedding requirements for the cows may be minimized. The duplication in shelter for resting and in feeding space may be no more than the cost of mechanization for feeding in the stall barn. There can be little doubt that a 10 or 12-hour period for feeding and daily outdoor exercise will prove to be beneficial in maintaining the dairy herd in good physical condition and at a uniformly high level of production efficiency the year round.

Milking time has been found to range from 15 or 20 cows per hour to 30 or 35 cows for the more efficient operation in the stall barn. Carrying milk to the milkhouse is time consuming. The 1½-in. CIP pipeline milker is expensive to install and clean. A new piece of equipment now under observation uses a 1-in. Tygon plastic hose that is arranged for CIP operation, except that it is cleaned in its position wrapped around the small milk receiving tank that is wheeled down through the barn as the milking progresses. The fact remains that

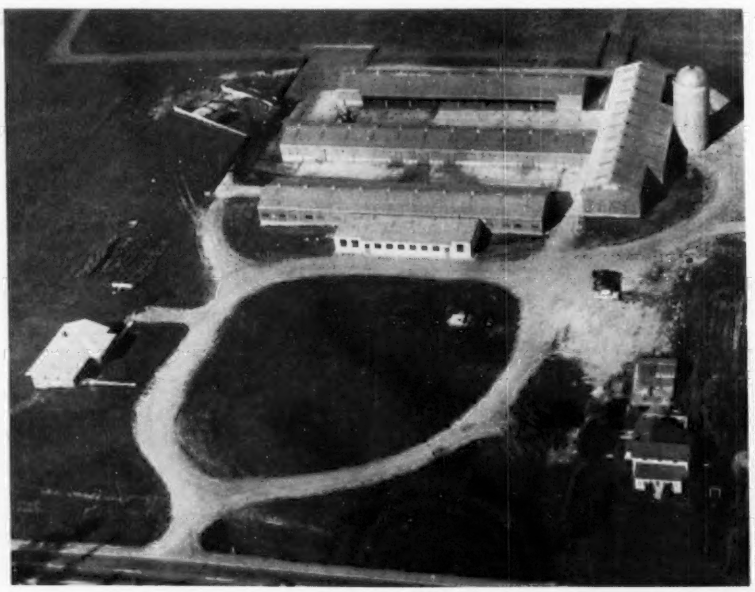


Fig. 2 Air view of university farm dairy unit

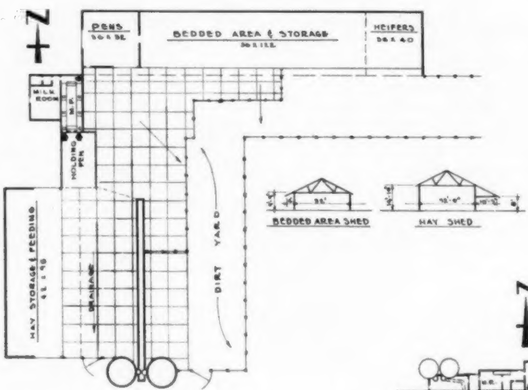
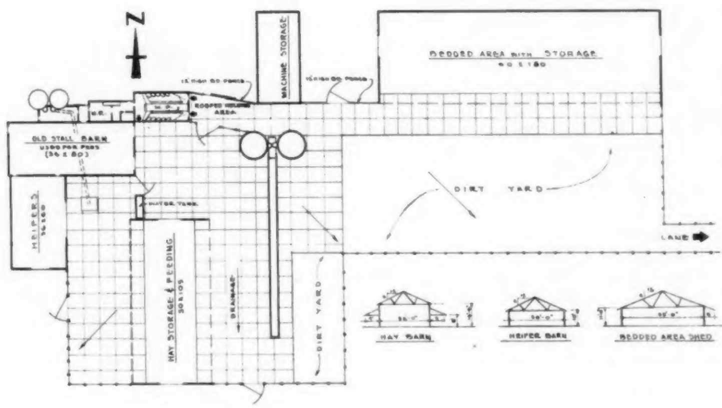


Fig. 3 *(Left)* Typical loose housing layout for 60 cows

Fig. 4 *(Below)* Loose housing planned for the expanded herd (125 cows) with efficient use of existing stall barn



the most efficient and best place for milking cows and producing quality milk under the most favorable conditions is an elevated-stall milking room equipped with CIP pipeline milker.

The holding area referred to above may be inside the stall barn or in a covered or partly covered lot adjacent to the milking room. Sometimes cows are held in a holding lane in the service alley of the barn.

Calf and maternity pens may be located convenient to the milking plant, but should never be a part of it. Less expensive construction is acceptable and should be used wherever possible for young stock and dry cows. However, for maternity pens and young calves, one must choose between insulated, warm housing in which individual calf stalls may be used, and open, cold shelter with deep heating manure packs for warmth.

Loose Housing

A recent survey indicates that there are over 600 loose-housing systems in Wisconsin, the remaining barns on 101,000 dairy farms being almost entirely of the stall type. The advantages of loose housing, even in the cold, snow-blown climate of the state, are being well demonstrated on most of these farms. A few of the existing systems are not complete enough for convenient use and others have not been as well planned, equipped, or operated as they should be. A loose housing system must be well planned and complete, at least to an acceptable degree, for satisfactory operation in all seasons.

The advantages and disadvantages of loose housing listed in Wisconsin Bulletin 503, dated June, 1953, entitled "Loose Housing or Stanchion-Type Barns," will not be repeated here, except to emphasize that loose housing responds to well-engineered planning and arrangement of buildings and equipment. In fact, it has been amply demonstrated that a system that is expected to operate at maximum efficiency must be planned right, built right, and run right. Likewise, successful operation of a loose-housing system requires a good dairyman. While there are exceptions, we do not, as a rule, expect a poor housekeeper with a stall barn to do better with a loose-housing system.

The requirements for loose-housing design were prepared by a sub-committee of Regional Technical Committee NC-23 and were published in the *Journal of Milk and Food Technology*, November 1956, pp. 302-312, vol. 19, No. 11. Most of the successful existing loose-housing systems in the state have been planned to meet the requirements of these standards.

Opportunities for mechanizing the loose-housing system for each of the areas would include the following:

Resting Area. Manure removal may be with power equipment. Bedding may be chopped and stored overhead, while baled bedding may be stored along the rear section of the resting shed or above. It is a good plan to provide sufficient bedding storage for yearly needs.

Hay Feeding. Feeding may be directly from storage or adjacent to storage. Equipment is available for placing hay in storage and for drying or conditioning in storage. Since the ground-level, hay-storage unit is commonly used to form a windbreak and to provide snow protection in northern areas, the drier duct should be located along the rear of the building with sectional, removable ducts extending toward the feed manger side of the structure. When hay is stored more than 10 ft deep, boxes with top end closed, made of light plywood material, 16 in. square and 4 to 6 ft long may be used to form riser flues in the hay 6 to 8 ft on center in each direction. Feed mangers must be designed to prevent wasting of hay if cows are to be kept from lying down in the feeding area. This point is of utmost importance for dairy cows.

Silage Feeding. Silage may be fed directly from a bunker-type silo, or it may be fed mechanically by the use of a silo unloader and mechanized feed manger. A covered feed manger will keep out rain and most snow, while a covered feed area will keep the cows dry when feeding during a rain. However, the advantages of sunshine in the feeding area should also be noted. Manure will tend to thaw much more readily when the sun strikes it. It is also well for the designer to keep in mind the fact that, when limited quantities of corn silage are fed, there should be enough bunk space so that all animals can feed at one time. This will give all cows an opportunity to get their share of the corn silage, which is mostly consumed in the first half hour after feeding. Some cows would pick all the cobs out of the corn silage if given time enough. Grass silage is somewhat less palatable, and it is difficult to get the cows to eat enough to meet their nutritive requirements unless it is before them most of the time. In cold weather grass silage tends to freeze more readily than corn silage. Therefore, it is better to feed grass silage in a short section of the silage feeding manger and place it in the manger to a considerable depth so that freezing will be minimized. This fact should be kept in mind when selecting a bunk feeder.

Yard. It is important that the paved portion of the barnyard be elevated above surrounding ground level as much as possible (1 or 2 ft is suggested) and that the pavement be given a good slope to drain away from the buildings. The need for proper site selection and development cannot be overemphasized. The pavement should be laid out so that the cows can be confined to the paved area in unfavorable

weather or when the rest of the yard is muddy, and so that power equipment can be used to scrape all parts of the yard. Temporary storage adjacent to the yard is necessary for manure storage when hauling to the field is impractical. Of course all manure must be hauled out before fly season. Where possible, it is a good plan to provide a ramp with the manure spreader below for loading barnlot scrapings. Protection for the operator should be provided so there will be no danger of the tractor being run over the edge of a manure pit or ramp, as, for example, scraping into a slot located over the centerline of the spreader. The paved portion of the yard should include all standing areas for feeding operations, and paved lanes or ramps should be provided in all traffic lanes. However, a solid block of paved area is the most convenient.

Holding Areas

Holding areas are still a problem. They should be accessible for power cleaning and a convenient drain for washing with water is desirable. A full enclosure has the advantage of offering an effective place for fly control by use of a fogging system.

Loose housing should keep the cows clean and present a favorable consumer impression. It should provide dairymen with complete facilities to minimize the effects of emergencies such as herd testing and sorting, isolation, and confinement. The designer should recognize that adverse weather conditions and changes in seasons should be considered for the purpose of avoiding emergencies and extra work for the operator. Frequently it will pay the dairyman to plant some trees for a shelterbelt and snow stop for his barns and yard area. Fire losses may be minimized by the separation of buildings. Fire gaps of 20 to 30 ft will often save a building when there is a fire in the structure adjacent to it.

Auxiliary equipment will also help control emergencies. An auxiliary source of electric power or a convenient hookup for tractor operation of the vacuum pump is almost indispensable. The advantage of auxiliary electric power supply of adequate capacity is that all operations may be carried on under normal operating procedure when the high-tension line power has failed.

Special yard-cleaning equipment is needed for snow removal and for the removal of soft and honeycombed ice and snow before warm weather changes it into the slush stage. The temporary manure storage, as previously indicated, located along one side of the barnyard and several feet below it will provide a very convenient place for disposing of a large volume of winter accumulations in a very short period of time. Another plan is to use a roll-over scraper pulled by a three or four-plow tractor equipped with chains for removing the softened material to an adjacent lot outside of the cow yard.

The calf and service barn should be arranged for power cleaning. Pens for calves located in cold barns or sheds should have a deep manure pack, and pens located in warm buildings would no doubt provide both individual stalls for the very young calves and pens for the older calves. Maternity and isolation pens are required for the cows. One service stall is recommended for each ten cows, and the location of the service barn should be convenient to the milking room and arranged in such a way that cows can be directed to the service barn after milking when this is desired.

The farm milking plant may be mechanized with bulk feed storage located overhead or in a weathertight bin outside and a conveyor system with metered feeding. Elevated stalls are essential for the convenience of the operator. Controlled warm water with sanitizer added, and with an outlet at each stall, is a sanitary and time-saving device for the milking operation. The CIP pipeline milker and bulk milk tank are already being widely accepted by dairymen and should form a part of the equipment in the farm milking plant. A milk meter mounted at each stall will aid in determining the amount of milk each cow is giving. When records are made one day each month, milk meters may be used for that one day only. Testers frequently carry milk meters with them.

The farm milking plant must be heated to prevent freezing and to control moisture. Complete plumbing is a sanitary requirement. Other general requirements include the need for extra bedding storage for reserve supply.

Summer pasture will add to the cows' comfort, and bluegrass sod is suggested. Pick a well-drained site and provide at least one acre for every five cows.

The designer should keep in mind that the design standards for the loose housing system which he uses include all necessary provisions for consistently high quality milk production and especially that all market requirements are satisfied. The dairyman must know that his housing system will satisfy regulations under which he must operate. He will be interested in obtaining a dairy cow housing system which will be convenient for him to work in; and if he must hire labor, it should be the sort of layout which will attract good labor. The entire facility should follow a well-balanced design adaptable to future expansion and the cost of which will fall within a reasonable price range. The housing system should be large enough to permit profitable operation, and most dairymen will be interested in a facility for which adequate financing is readily available. Others will be concerned about alternate uses for the facility and possible resale value in case liquidation should become necessary.

Design for Loose Housing Under Wisconsin Regulation

On January 7, 1960, a statewide committee representing local health departments, the Chicago Board of Health, State Department of Agriculture, dairy industry, State Board of Health, and the Barn Equipment Association cooperating, prepared and released the current revision of "Recommended Minimum Specifications for Loose Housing for Dairy Cattle in Wisconsin." While the standards prepared by a subcommittee of Regional Technical Committee NC-23 and published in the November 1956 issue of the *Journal of Milk and Food Technology* were closely followed, some changes were made. In the years following the publication of the standards, several hundred loose housing systems were established and operated with minimum regulation. Experience proved that this was not enough regulation to safeguard grade A milk production. Incomplete loose-housing systems, lack of equipment for cleaning barnyards, and failure of dairymen to appreciate the importance of good housekeeping were major factors in causing the deficiencies found in a study conducted in the early spring of 1959.

In setting up regulatory standards for loose housing, every effort has been made to prevent the establishment of incomplete, poorly planned, and inadequately equipped dairy cow housing. If a dairyman having an approved loose-housing system is found in violation of acceptable grade A milk production practices, the plant fieldman will be in a position to issue his orders on the basis of what he knows the dairyman can do to solve the problem. While this may at first seem to be an uncompromising approach to the dairyman, the successful operators have not hesitated to support the new regulatory standards. They feel that it is for the dairyman's own best interest that he have a complete, workable loose housing system. There are over 600 known loose-housing systems in a state with 101,000 dairy herds and a poor or inadequate system definitely does harm the popularity of the minority system.

Under the recent regulations two copies of plans or sketches of each of the component buildings of the loose-housing system must be presented to the regulatory agency responsible for inspecting the milk supply on the farm, giving dimensions, construction, lighting, and ventilation information for each. Dimensions and construction must be indicated for the cow yard, watering and feeding facilities, complete layout of sewage disposal facilities, location of water supply in relation to sewage disposal, barn lots, etc. The number of cows to occupy the facilities must be indicated.

The milking room must meet the same general requirements and structural standards as currently apply to the milkhouse or milkroom. Here again good housekeeping with minimum time expended can be achieved only when the walls are smooth and easily cleaned, the floors sloped adequately to drains, and the drainage grilles of regulation size and properly located. Good lighting, both natural and artificial, is covered in the regulations; also included are such items as insulated construction, heating, and ventilating. Exceptions in which the milking room is not like the milkroom include the flow of cows through the milking room, presence of feed, direct toilet room access, and inward swing of

door from the milkroom. A vestibule between the milkroom and the milking room is not required for a farm milking plant unless there is a direct connection with a stall barn. A good operator would certainly be expected to keep manure washed from the floor and grilles during milking.

A washroom complete with hand washing facilities and toilet should be planned as a part of the farm milking plant. The washroom may not open off the milkroom. Likewise, a utility room for a heating plant, fuel storage, hot water heater, and vacuum pump is recommended; the room should be lighted, ventilated, and equipped with drain and chimney. Heating of the farm milking plant to prevent freezing and to maintain 50 F operating temperature when in use is a requirement on the Chicago grade A market.

Feeding in the milking room is permitted, and feed storage must be dusttight and rodent-proof.

Milking barns are exempt from the milking-room requirements, their classification for regulation being the same as for conventional stall barns.

Waste disposal is spelled out in detail, the toilet room waste going to a septic tank and underground disposal field. The milkroom and milking room waste must go to a rectangular concrete settling tank with removable slab top at grade for accessibility as regular periodic cleaning is required. The settling tank must have a minimum of 20 gal net storage capacity per cow milked. Disposal is by underground methods or other as approved by a state district sanitary engineer. To prevent odors from entering the farm milking plant, deep-seal traps, roof vents, and the use of 4-in. cast iron sewer pipe within the building and either cast iron or vitrified clay outside the building are required.

It is interesting to note that water for washing udders is to be furnished by a mixing valve for temperature control and that a sanitizing solution is to be metered into the wash water for washing and sanitizing udders and teat cups.

The holding area is to have 25 sq ft of paved area and enough of the holding area is to be roofed to hold two cows for each milking stall. Cleaning after each milking with removal of manure from access to cows is a requirement. Some dairymen are taking this to mean an enclosed holding area with a frostproof floor drain and enough protection to prevent the manure from freezing for most of the winter period. This enclosure may be ventilated enough in summer to keep the cows comfortable and also to make fly fogging possible.

For the initial herd and for approval, the bedded area must provide 75 sq ft per cow of well-bedded, dry, wind-protected, properly ventilated resting area with enough clear height to maintain at least 6 ft of head room above the manure pack at all times. At no time is the operating minimum to be less than 60 sq ft per cow in the bedded area. The bedded area must be managed daily to keep cows' udders and flanks free of manure. No feeding, watering, or cross traffic is to be permitted. Only healthy cows are to be permitted in this area. No direct passage from feeding area to bedded area is to be permitted within a building.

Building and lot arrangement should be planned to provide maximum protection for cow yard and bedded area from prevailing winds, flooding by storm water, and drifting snow. (The last three words are the author's.) The floor of the bedded area is to be leveled and filled to 8 in. or more above outside grade and yard level and either paved with concrete or filled with crushed rock or other suitable material. In the latter case concrete barnlot paving will extend into the shed 4 ft from eave line and slope ½ in. per foot away from the building and out into the yard. Preservative-treated, windtight, wood planking applied to the inside face of framing or poles or concrete high enough to accommodate a 4-ft deep manure pack is required.

Ventilation sufficient to keep building and bedding dry; natural light, 1:20 ratio of opening area to floor area, and artificial light consisting of a 100-watt bulb to each 400 to 500 sq ft of floor area are also requirements. The bedded area is to be thoroughly cleaned before fly season.

A cow yard area of at least 75 sq ft per cow as well as areas adjacent to feeding, watering, bedded area, and farm milking plant are to be paved. The author wishes to observe that the yard should be arranged for accessibility to all areas by a power-operated scraper, since regular cleaning is required. A minimum slope for drainage is established at ¼-in. per foot.

The feeding area is to be paved, sloped away from manger, and readily accessible for cleaning. Mangers are to be of a type that will prevent wasting of hay in standing areas. Temporary manure storage areas are to be provided. Adequate equipment for snow removal, yard scraping, and manure removal is to be available when required.

Watering facilities are to be provided in the paved area and away from openings into the bedded area; they are to be protected against back-siphonage.

Facilities for calves, young stock, and for cows requiring special attention such as breeding, calving, clipping, grooming, and treatment, with enough stanchions for 10 percent of the herd, and at least one maternity pen for each 20 cows, are required. Provisions are to be made for diverting cows when leaving the milking parlor.

The cows must be kept clean. Flies are to be controlled at all times.

Combining Dairy Farmstead Components for Economical Operation

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THE full contribution of dairy farmstead facilities to efficient production can be realized only when production buildings are well planned, well arranged, and lend themselves to the use of associated mechanical and electrical equipment and acceptable management practices.

Farmstead studies and observations have repeatedly shown a great need for better internal planning of individual buildings; a better relationship among complimentary and supplementary buildings, lots, and equipment; more efficient methods of milking and milk handling; better methods of handling animals and waste products, and better, more efficient methods of handling feed.

Significant progress has been made in the development of buildings, equipment and management practices to increase the effectiveness of dairy farmstead operations. But the rate of concrete change on farms has been relatively slow. This slowness has been variously attributed to the existence of a physical facility representing a high investment, the natural resistance to change, and compelling sanitary regulations. But perhaps, most of all, it is due to a confused idea of just what can be done and what might be the result in specific cases. The integration of buildings, equipment and production methods remains a hazy area for farmers and many of those in position to advise them. This is especially true where groups of buildings are required—where the effects of internal and external arrangement must be combined with an assembly of diverse methods and equipment.

Farmstead planning is confused by the fact that equipment, to say nothing of the structures with which it is used, is made and sold by many manufacturers and dealers. The complete package is still something to be worked out at the local level. It is often attempted by people not well grounded in the over-all picture. The frequent result is that it is not well done, involves many unnecessary compromises and even absolute mistakes.

It must be constantly borne in mind that flexibility of the entire system is of utmost importance because of rapidly changing technology. A good solution last year may not be a good solution now and very likely will not be the best solution next year. It

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must be possible to change the facility with changing production requirements and farming methods.

Organization: Internal and External Arrangement

Too often farmstead arrangement is considered to be an essentially static thing. It is true that, in most cases, changes come relatively slowly; however, if one follows the transition of any farmstead over a period of a few years, it will likely be found that rather a great number of changes have taken place. The fault is that these changes have occurred one at a time because of particularly disagreeable situations, with little thought of an ultimate goal.

Since relatively few farmsteads are being built outright, transition from the existing to the desirable is the rule. Consider, too, that the maker of these far-reaching decisions is frequently almost totally lacking in experience with the whole problem. His decisions are long lived and drastically modifying them, once they have taken concrete shape, may be a waste of time and money.

A clear-cut goal and a carefully made plan to meet the total need can lead to good farmstead organization even though major improvements are made in stages.

It is becoming more apparent that decisions made to improve dairy farmsteads must be on the basis of efficiency and flexibility. Labor efficiency will pay now and in the future. Fexible buildings and equipment will permit changes with production and marketing demands and new farming methods. Flexible buildings not only provide adequate shelter for livestock and stored crops, but also permit the maximum use of mechanical equipment in moving feed and bedding into the building and moving waste products out. Lots, too, should be easy to get into and out of and paved for easier cleaning. The number of gates should be minimized and lanes should be conveniently located.

Internal arrangement is important because it helps to determine the speed, ease, and adequateness with which milking, feeding, and cleaning operations can be done. Certain aspects of it also aid materially in providing better cow comfort, which is reflected in better production, a longer productive life and fewer injuries.

Frequently the external arrangement of building groups is as important as the types of individual buildings. Several functions are served by location alone. Among these are windbreaks for open lots, arrangements for easy cleaning, space for maneuvering machinery, maximum exposure to sunlight, proper drainage, accessibility for bulk trucks and other large service vehicles, convenient locations for handling animals into and out of the farmstead area, and easy and safe access for the operator.

In addition to these (which may be thought of as relating to the dairy area alone), consider the dairy plant's association with other farmstead facilities. Grain storage and processing areas should be located in such a way as to maximize the efficiency of moving processed feed to a storage point within the dairy building group. Its relationship to the residence is also important from the aesthetic view as well as for accessibility.

Many studies of farmstead labor have emphasized the use of equipment to overcome poor layout. In situations where layout is already determined and relatively fixed, this may be the proper solution, but it is erroneous to assume that more and better equipment is the whole answer. Even the work of an efficient machine can be supplemented by good arrangement. Good arrangement has no operating cost and will almost always reduce the cost of installing and operating the essential equipment.

In the name of fire protection, many farmsteads have become big, spread out and difficult to use. But compactness is also a virtue. It would seem that reasonable protection can be gained in most instances by the distances that will prove necessary for good arrangement around a central farmstead court (14, 23)*. In loose-housing dairies, the idea of close proximity of at least some related buildings has been accepted and improved efficiency has resulted.

The direction of prevailing winds and the path of the sun will influence external arrangement decisions. Open-front buildings and livestock yards should be arranged so that animals are protected from winter winds and exposed to cool summer breezes. In most cold areas, protection is needed against the prevailing winds from the northwest. In summer, the cooling effect of southwest breezes should be exploited. Livestock yards and silos should be located so that summer breezes do not carry odors toward the residence. Ideally, these areas should be located northeast of the dwelling. A southwest location should be avoided if at all possible.

Open-front buildings or those having large glass areas should be faced to the south or southeast. This will allow better use of the warming and drying effect of the sun's heat during the winter, while excluding most of the hot, direct rays in summer.

Systems Choices and Comparisons

Dairy buildings, considered in the same way as any production tool, have certain functions to perform. Basically, the buildings should provide the necessary enclosed facility and be arranged and equipped in such a way as to allow the performance of the necessary jobs with the least expenditure of time and effort.

Serious consideration should also be given to the questions of alternative ways of providing the requirements and suitability of the system with regard to modification to meet changing herd sizes and changing requirements of any of the basic considerations.

The stall barn has been the traditional concept of commercial dairy housing, and until the early 1940s, its ability to provide the essential requirements went largely unchallenged in the major dairy areas. A significant shift in emphasis to loose housing has taken place in recent years, mainly because of the need for increased efficiency, physical facility cost reduction, and flexibility for expansion or conversion to other productive uses.

In many cases, the choice between systems remains a major hurdle. But this choice must be made early in the planning stage, because it markedly affects many aspects of the development of a final design.

Various writers have pointed out numerous advantages and disadvantages of each system. The farmstead engineer should be aware of these considerations, even though some of them would appear, from all available research data, to be questionable in relation to a dairy farm operated mainly for the production of market milk.

Sometimes the choice is a purely subjective one based on improper emphasis or a misunderstanding of alternatives. Frequently, however, the decision is based largely on the need for utilizing the facility already existing on the farm. The latter situation brings up many complex problems, and its significance in planning dairy farmsteads cannot be overemphasized. However, it is essential to avoid compromises with existing facilities that will critically limit the primary purposes of reorganization — efficiency and flexibility.

For situations where relatively good stall barns (having size and shape to accommodate the changes necessary to get adequate stalls, work alleys, etc.) exist and where, by good planning, improved methods and equipment can be utilized, the choice becomes very complex.

When considering stall barns, one further choice must be made early. Whether to use a conventional stall barn with overhead storage for hay, bedding, and perhaps ground feed, or a single-story barn with feed storage in separate, less expensive, shed-type structures. Two-story barns have the serious disadvantages of being higher in cost and more difficult to expand when necessary to provide space for an increasing milking herd and limited in use for other purposes if the need should arise. Although the choice has some bearing on the efficiency of the milking and milk-handling operations, its major effect is in the storage and handling of hay crops. In a suitable arrangement, hay can be stored in one structure for both the producing and non-producing parts of the herd. It is likely that the operation of moving hay into the storage structure will be simpler in the open-type, one-story structure, although it is doubtful that improved efficiency will be realized in distributing hay to stalled animals because of the more remote location of storage. It is interesting to note, however, that in one series of energy expenditure tests, it was shown that climbing a ladder into a haymow 8 feet above the stable floor required as much effort as walking 200 ft on the horizontal (6).

Another important consideration in stall-barn layout is whether to face cows toward a wide, center feed alley or face them toward narrower feed alleys adjacent to the outside walls. At the time when hand milking and manual manure handling were prevalent, the face-out system was usually recommended. About 80 percent of the time

*Numbers in parentheses refer to the appended references.

spent in the milking operation was spent behind the cows. In stall barns equipped with pipeline milkers and mechanical gutter cleaners, the major unmechanized operations — feeding of hay, silage and concentrates — are all performed at the head end of the cow. Face-in stall arrangement provides for the mechanization of feeding, without complicating the use of new equipment for manure removal and milk handling.

Loose-housing systems for dairy cattle are made up of a series of rather distinct units. The function of the various parts and the important relationships among them have much to do with the satisfactory performance of the system. However, detailed descriptions of these areas and the operations which take place in them cannot be covered here.

Milking, Storing, Handling, Feeding and Cleaning Operations

Milking Operations. Operations directly associated with milking, milk handling, and sanitation practices require from one-third to one-half of the total working time in farm dairies. The planning of these operations and the areas in which they take place is of paramount importance.

The rate at which the milking operation can be performed, consistent with good milking practice, has been the primary basis for evaluating the efficiency of milking areas (Table 1, Fig. 1). In many early labor comparisons, milking rooms were found to allow faster milking than was then being done in stall barns. Much of this difference seems to have been due to the comparison of pipeline-equipped milking rooms with bucket milker use in stall barns. Later studies indicate that the milking rate in recent-type stall barns equipped with pipeline milkers (with one man using three milking units) is about the same as that of double-line, side-opening, or walk-through milking rooms utilizing three to four milking units (Table 1). However, there is little doubt that less effort is required to milk in milking rooms (19).

TABLE 1. MILKING RATE (COWS PER MAN HOUR) FOR VARIOUS PIPELINE-EQUIPPED MILKING AREAS

Stall barns	Milking rooms			
	Double 2 side opening	Double 3 side opening	Double 3 walk through	Double 4 herring-bone
(3 units)	(4 units)	(3 units)	(4 units)	(4 units)
30	28	30*	32	43

*From appended reference (20) all others from reference (19).

It should be pointed out that comparisons based on a very limited number of cases can be misleading, even though the milking areas being compared are similarly equipped. One study of 105 farms having similar herd sizes and similar facilities showed that, due to work methods, the least efficient operator used four to five times as much labor to produce milk as the most efficient (27).

The use of pipelines for handling milk speeds up the whole process of milking, mainly because the operator is able to use more milking machines effectively. The development of in-place cleaning procedures has eliminated the major operational drawback of pipelines. In addition, the production of individual cows can now be collected, weighed and inspected in pipeline systems.

The cost of installing the long pipelines required in stall barns has been a great deterrent to their general adoption. The introduction of "dumping stations" and portable plastic pipelines as an alternative is attractive from the cost viewpoint and offers most of the advantages of the more expensive fixed pipeline.

The herringbone milking room is a relatively recent development, but according to most studies (1, 2, 16, 17, 21), it allows a marked increase in milking rate. This is due to its compact arrangement which greatly reduces travel and allows the operator to more fully use a larger number of milking units.

The number of operators and the number of machines utilized per operator significantly affect efficiency (22). Too few machines limit the operator's output by creating too much idle time, by wasting of time in operations usually considered unnecessary, or by overdoing the necessary jobs. Too many machines result in poor milking because of the tendency to rush necessary operations and failure to remove machines when milking has been completed.

In general, it appears that for in-line stalls, six stalls (double 3) and three milking units give the best balance. In herringbone milking rooms, one operator works at high efficiency with eight stalls (double 4) and four milking units. Although it is not universal, there is some feeling that increasing this to ten stalls (double 5) requires a superior operator if overmilking is to be avoided (16).

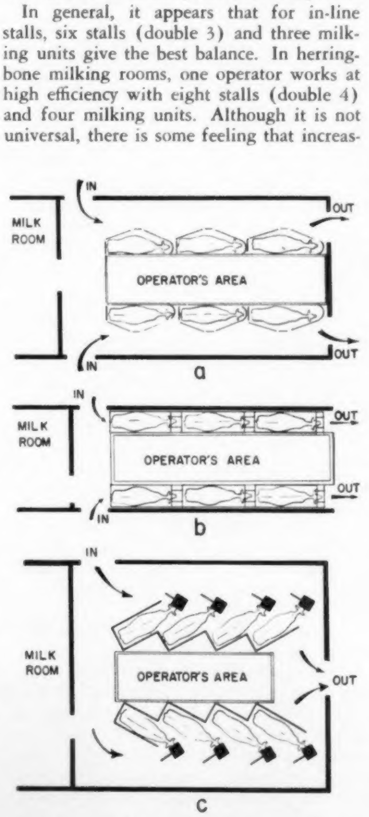

Fig. 1 Types of milking areas in common use: (a) double 3 with side-opening stalls, (b) double 3 walk through (or chute), and (c) double 4 herringbone

Several reports have indicated a substantial reduction in efficiency (25 to 35 percent over-all) when more than one operator works in a milking room of usual size. It seems advisable, even in dairy operations where more than one man is necessary because of the total work load, to plan milking rooms for the use of one man. The second man could be more fully occupied at other necessary jobs. In very large operations, two one-man milking rooms would seem preferable to one large milking room in which two men have to work in concert.

Milking rooms are being used in conjunction with stall barns to some extent. One of the discouraging aspects of this combination is the absence of quick and easy methods for handling cows from the stall area to the milking room and back again. As it is commonly done, it involves either the use of large holding areas, both prior to and after milking, or a second man whose time might not be fully utilized unless he can fill in idle time with other short time operations. In any event, milking rooms mean easier milking and more efficient grain feeding.

Concentrates Handling. Bulk handling of ground feed eliminates manual handling in loose-housing systems and reduces it to only the feeding operation in stall barns. The delivery truck or the distribution system from the processing area can place it in an overhead bin or into a mechanically unloaded ground level bin.

There has been limited work on mechanized feeding of grain to stanchioned cows, but at present there is no generally accepted equipment or method. However, an inexpensive auger can deliver feed to a cart from a ground-level bin, or a gravity spout can deliver it to a cart from an overhead bin. With relatively little investment, this leaves only feeding to be performed manually.

In loose housing systems, bulk grain should be received and stored over the milking room or in adjacent mechanically unloaded bins. An auger or chain conveyor can maintain a supply in down spouts leading to meters at each milking stall. No manual handling need be involved and control of each cow's feeding is maintained.

Hay Handling†. Baled or chopped hay? How much hay compared to silage? These are basic questions to be answered before a final plan is prepared and the answers can make considerable difference in the ultimate system.

Baled hay does not permit elimination of manual handling. Most current baled-hay handling systems involve manual handling of every bale in each of five to seven operations. However, with the use of bale throwers, unloading wagons, elevators, mow distributors (or random-bale filling), this can be reduced to only one major manual operation, that of moving the hay from storage to the feeding device.

In long stanchion barns, along long feed bunks, or where bales are stored some dis-

†Van Arsdall (24) has thoroughly covered the economic aspect of mechanizing feeding operations with presently available equipment.

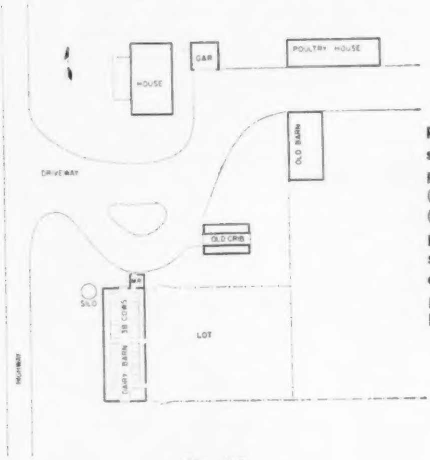

Fig. 2A

Reorganization of existing farmsteads can take many forms depending on early decisions. (Fig. 2A) An existing farmstead. (Fig. 2B) The same farmstead expanded and reorganized for stall housing of 156 milking cows. (Fig. 2C) Farmstead expanded and reorganized for loose housing of approximately 160 cows

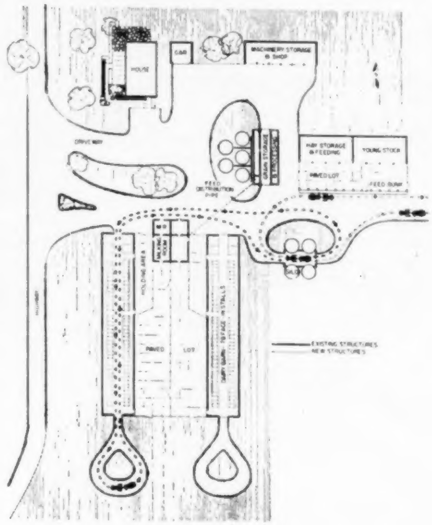

Fig. 2B

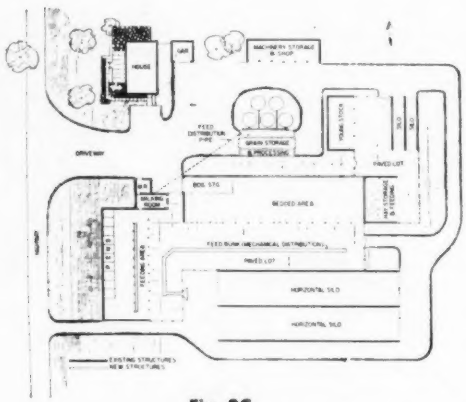

Fig. 2C

tance from the feeding area, bales can be hauled and distributed with trucks or wagons to reduce effort, but this involves three manual handlings in removal from storage, piling on a vehicle and unloading.

Chopped hay allows complete mechanization in that augers, conveyors, blowers and gravity can be used in handling and distribution. In loose-housing systems, it can be self-fed from storage, mechanically fed, bunk fed from side-discharge unloading vehicles, or fed from self-feeding racks. With ground-level storage, no manual handling is needed. With elevated storage, the only manual handling is pushing the hay from storage to a floor or wall chute.

In stall barns, chopped hay normally involves removal from the mow and distribution in the manger. If the cows face in and the distance between stanchion curbs is about 12 ft, feeding may be done with a side-discharge unloading vehicle. This vehicle can be loaded with a tractor scoop from ground-level storage or by gravity from overhead storage.

Dustiness of chopped hay may be a problem in stanchion barns, but is of little consequence in loose-housing systems.

Silage Handling. It is possible to completely mechanize silage handling. However, requirements depend on whether vertical or horizontal silos are used and whether cattle are loose-housed or kept in stalls.

Unloading wagons or dump trucks and an elevator or blower allow mechanical placement in storage. Distribution of silage in either vertical or horizontal silos can be done mechanically as they are filled. In vertical silos, distribution is important but compaction, except at the very top, is usually considered unnecessary. In horizontal silos, both distribution and compaction are important.

Removing silage from storage is usually a manual operation even though it requires more time, effort and personal danger than silo filling. But either machinery or livestock can do this chore. Self-feeding is easily arranged and controlled with horizontal silos in loose-housing systems. However, there is still some question regarding low silage intake, and spoilage and wastage is a problem in forage deficient areas. Self-feeding directly from vertical silos is difficult to arrange and has not been widely used.

Mechanical silage removal and feeding fits either loose or stall housing. The mechanical silo unloader for vertical silos and the tractor loader for horizontal silos can deliver the silage to a mechanical feeder or to a feeding wagon. A side-unloading wagon will deliver and meter it into indoor mangers or outdoor feed bunks.

Mechanical feeders are practical when cattle are free to go to them, but they appear impractical at present for stall barns. Auger feeders or single endless chain types which permit feeding from both sides reduce investment and present little problem in quantity control. With types which make only one pass along a bunk before discharging silage at the far end, there is a serious problem of controlling quantity.

Fence-line feeding from a paved strip is another method. Here cattle eat through a special fence, with silage distributed by an unloading wagon or directly from a nearby horizontal silo with a front-end loader. This system can also be used in green feeding, where pasturing is not a part of the management program.

Serious thought should be given to location when building new silos. There is considerable merit in having them away from the barn and close to mechanical feeders (Fig. 2). This means better equipment access, simpler distribution, and less likelihood of interference with future expansion. In any event, silos should not be in the barn lot nor too close to the residence.

Bedding Handling. Of all the materials used on the dairy farm, bedding is perhaps the least adaptable to complete mechanical handling. The nature of operations involving bedding and the quantities involved appear to make mechanization impractical in stall barns, but there are several things which can be done to save time and effort. Bedding, in large or small quantities, should be stored close to or over the stalls. Shavings, sawdust, or other fine materials can be

stored in hopper bins for gravity filling of distribution carts below. Baled straw, like baled hay, requires several manual handlings. If it is to be used, there are advantages in chopping it.

In loose-housing systems, it is practical to store bedding either above the bedded area or in an enclosure at its side or end. If stored above, it can be loaded by gravity (except in the case of bales) into a spreader or an unloading wagon for general distribution. Some additional hand spreading may be necessary. Shavings or sawdust can also be delivered to and stored in a bin in the bedded area. If possible, the bin should be located for filling from the farmstead service area and have doors on the inside large enough for removal of bedding with a tractor scoop. The tractor scoop can be used directly for general distribution.

Manure Handling. Manure represents the greatest tonnage of all materials handled on dairy farms. Fortunately, good equipment for handling it in stall barns exists and is in widespread use. Most systems have elevators for discharging directly into the spreader. This feature eliminates a separate loading operation and should be incorporated into any mechanical system. Box stalls and calf pens are less easily mechanized, but manual effort can be minimized by running the gutter cleaner through or past them and covering it with removable plates. Manure can then be scraped into the opened gutter for relatively easy removal.

In loose housing, the feeding area and paved lot have to be scraped clean frequently, while the bedded area is cleaned less often. Both of these operations can be done with power equipment at little added expense, since tractor, spreader and front-end loader are standard items on most farms. Perhaps the only "extra" investment needed for complete mechanization of manure handling for loose housing is a scraper-blade attachment.

Planning Dairy Farmsteads

The common practice of laying out farmstead improvements has been (and is yet) largely based on the accomplishment of isolated objectives one at a time, with too little emphasis placed on the development of a facility with better over-all organization. What is needed is a thoroughly worked out plan for providing the right buildings, located in the right places, with the necessary lots and areas, and the whole layout provided with a "system" of equipment for handling the jobs in a logical order from beginning to end with a minimum of supervision.

In order to be effectively done, dairy farmstead organization must be viewed in ways more critical than have ordinarily been used. In some respects, many designs have not been either sufficiently intensive or extensive. They have not been intensive enough to account for the influence of the various job segments on the labor expenditure in the "dairy barn" proper, nor have they been extensive enough to account for the efficiency effects on the whole farmstead labor picture.

Considering that most farmstead "engineering" is done by other than engineers, one of the engineer's greatest obligations is to relate buildings and equipment to best current production practices in such a way that the likelihood of gross misuse is small.

Standardization in manufactured and packaged systems (thus limiting choices) might eventually lead to easier choices in farmstead design. It is difficult to believe, however, that farmstead solutions will become as standardized as field needs in the near future. As a rule, the integration of buildings and equipment, with its many alternatives, will remain a problem to be worked out at the local level, since no one manufacturer or supplier makes or sells all that is needed.

Recently, some favorable steps have been taken to integrate buildings and equipment into working units at the manufacturer's level. A few buildings manufacturers are working closely with producers of farmstead equipment to provide a "systems engineered" farmstead facility. This important trend will surely grow and should tend to somewhat simplify the planning required to meet the needs of the ultimate user's peculiar situation.

Even this progressive step leaves the external arrangement of buildings and lots to the good judgment of the farmstead planner. A further step by manufacturers to show details of how their products fit into a whole operational picture would lead to better organization.

Most farmstead designers do not have the opportunity of evaluating the efficiency of the operational aspects of a farmstead facility as a whole. Indeed, few studies have related to this over-all problem. However, one can piece together a solution, if he has developed an understanding of available buildings, equipment and methods.

Just as the ultimate user of the farmstead facility is dependent on well laid out facilities and procedures, the farmstead planner is dependent on a general method of planning which can take into account routine matters as well as those concerned with the peculiarities of a particular farmstead.

The method outlined below, which some readers will doubtless find too general and oversimplified for their use, is one which the author has found to be workable. It involves:

1 A critical evaluation of existing facilities in the light of present and anticipated requirements

2 Choices among the alternatives that will likely affect future operations and needs

3 The development of an over-all plan to meet *all* present and anticipated requirements effectively.

Step 1, although difficult to do, is almost inescapable, because the usual problem is one of adapting and modernizing an existing facility.

The decisions mentioned in step 2 must be made, even though they may be tainted by subjectivity. These decisions, whether objective or subjective, must yield a point from which the whole plan can be projected.

Whether or not the finished plan of step 3 will be provided immediately is of relatively little importance. If it is necessary to implement the plan over a long period, a well-conceived, flexible plan is even more important, because, in such a circumstance, one should undertake to do first the things that will have the greatest over-all effect on operating efficiency.

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Pie-Shape Design for Dairy Corral Layouts

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DAIRY corrals with pie-shaped layout resemble a pie cut in several pieces. The design is also sometimes referred to as a "wagon wheel" layout because it roughly resembles a wagon wheel with the fences between the corrals resembling the spokes of a wheel. The origin of the "pie-shape" dairy layout is not definitely known, but it has been in use in California about 15 years for dry-lot dairying. This paper is intended to describe the physical features and suggest over-all designs for workable, satisfactory pie-shape dairy layouts. Those studied to date have all been in mild climates with winter temperatures not much below freezing, but there seems to be no reason why they will not work satisfactorily in colder climates if adequate shelter is provided for the cows.

The pie-shape layouts described in this paper are based on the best features of ten such layouts studied to date that range in size from 150 to 670 cows.

Shelters and structures for dry cows and young stock are not considered here because the advantages of pie-shape corrals are primarily for lactating cows. Some of their advantages over rectangular corrals are as follows:

1 The average distance from corrals to washing and holding pens (for elevated stalls) or the milking barn is much less. Average distance is only about 50 to 60 percent of that with the best possible rectangular corral arrangement, and only 15 to 20 percent of the distance in rectangular layouts that are most common.

2 All corrals are about equidistant from the washing and holding pens or the milking barn.

3 Separating a single cow from the herd takes only one man instead of the two usually required in a rectangular corral.

4 There are fewer corners in pie-shape layouts. The narrow end of the corral terminates in a gate.

5 Less travel is required in delivering feed to the fence feed bunks.

The disadvantages in some cases may be as follows:

1 A circular layout may not fit the only available site.

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2 Travel inside a corral to drive cows out for milking, if very far, may be more than in a rectangular corral of the same area.

The maximum practical capacity of a pie-shape layout is somewhat indefinite. Those we studied had capacities of 150 to 670 cows. The 670-cow layout could have been planned just as easily for 1,100 cows.

The corrals in all of these layouts could have been made larger by expanding them outward along their radii to accommodate more cows per corral. As many as 60 cows per corral are found in rectangular layouts and 45 cows per corral in pie-shape layouts. The maximum satisfactory number is probably considerably greater.

Following are some essentials that must be considered in planning a serviceable, satisfactory pie-shape layout:

Site and Drainage

The site should be selected so that prevailing winds, especially in the summer, will not blow from the dairy layout toward the dwelling. An alternative is to place the dairy layout as far from the dwellings as practical. It is usually best to allow space for future expansion. Dairies that are large enough for pie-shape layouts to be practical usually require a labor crew of 3 to 10 men. In California, most of them live on the premises, frequently no more than 100 to 200 ft from the milking facilities or corrals.

A natural slope of the corrals upward and away from the milking facilities will greatly aid drainage of pie-shape areas. A slope of 1 to 4 deg (roughly 1 in 50 to 1 in 13) may be ample, depending on soil conditions, amount of paving and precipitation. Five of the ten pie-shape layouts studied in California had corral slopes of about 3 to 11 deg (roughly 1 in 18 to 1 in 5). These steeper slopes were frequently of eroded, finely divided rock (sometimes referred to as "rotten granite") mixed with some soil. Even on 11-deg slopes, erosion may not be objectionable and much of the rainfall will soak in rapidly. This same type of soil—rock mixture also may be used satisfactorily as a soakage area for barn washings where disposal by other common methods is impractical or uneconomic.

Cross drainage of runoff from corrals usually can be provided somewhere between the perimeter feed bunks and the washing-holding pens. In one case where this was impractical, much of the runoff was from the corrals to the washing pens, then diverted through the washing pens to a soakage area 200 to 300 yards away that also served for milking room and milkroom washings.

Paving the entire dairy layout area simplifies drainage but is not considered economic for large dairies in California. Nevertheless, if the entire corral area is paved, less space is required per cow. Any partial paving should be in the areas of heaviest traffic, such as strips along feed bunks, around water tanks, and along fence lines from the perimeter feed bunks to the washing pens. Cows in the Middle West, in some instances, have no more than 200 sq ft per cow, including the open lot and feeding and bedded shelter areas. Very few large dairies in California have less than 300 sq ft per cow. In 18 layouts studied, 15 had over 400 sq ft per cow in the corrals; three with over 800 sq ft per cow were in areas with very little natural slope for drainage. Where paving the entire corral is not justifiable, draining each corral to the fence line between corrals is suggested by one contractor who has built pie-shape layouts. Concrete gutters at the fence lines can then carry the runoff away and will require very little slope. A uniform slope of 1 ft in 100 to 1 ft in 75 should be ample if the gutters are kept clean.

Water Supply

Dairy water use varies extremely. To meet milk production regulations in California, it is common to wash cows in string (or stall) milking barns with a hose and water pressures up to 45 psi. In some cases the cows are first prewashed with floor sprays in a washing pen. A washing pen is nearly always used with elevated stalls except for scattered dairies in the high mountain valleys of California where winter climate is much colder.

Water use in Orange County, Calif. (a mild climate), mostly in string barn layouts with rectangular corrals, has been measured with water meters for several years, showing the following total water requirements: *(a)* 80 gal per cow per day for lactating cows, *(b)* 35 gal per cow per day for dry cows, and *(c)* 625 gal per day for an average dairy herd. In many states and areas such large volumes are not used and total water requirements for lactating cows would be more nearly that for the dry cows (35 gal per cow per day).

The location of water tanks seems largely a matter of preference. It is common practice to place them anywhere between 12 ft from the perimeter feed bunks and 20 ft from the exit gate at the vertex. In Fig. 1 they are located in the fence line near the perimeter feed bunks so as to be on a paved area that covers only a small part of the corrals. In any case, locate them in the fence lines so each tank can serve two corrals.

Cow and Operator Traffic

Figs. 1 and 2 illustrate the cow and operator traffic routes for pie-shape layouts using elevated milking stalls and string

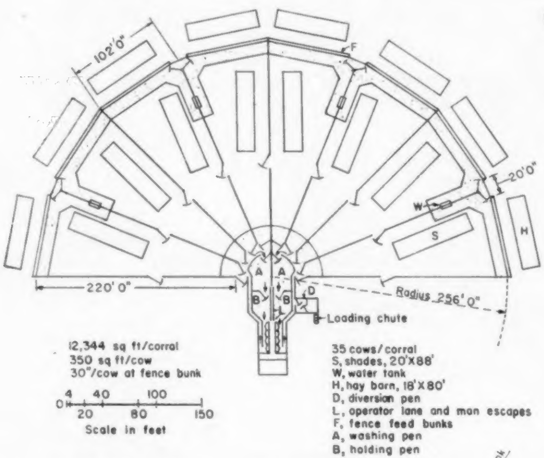

Fig. 1 *(Left)* **Pie-shaped corral layout showing relation to washing-holding pens for an elevated stall milking room**

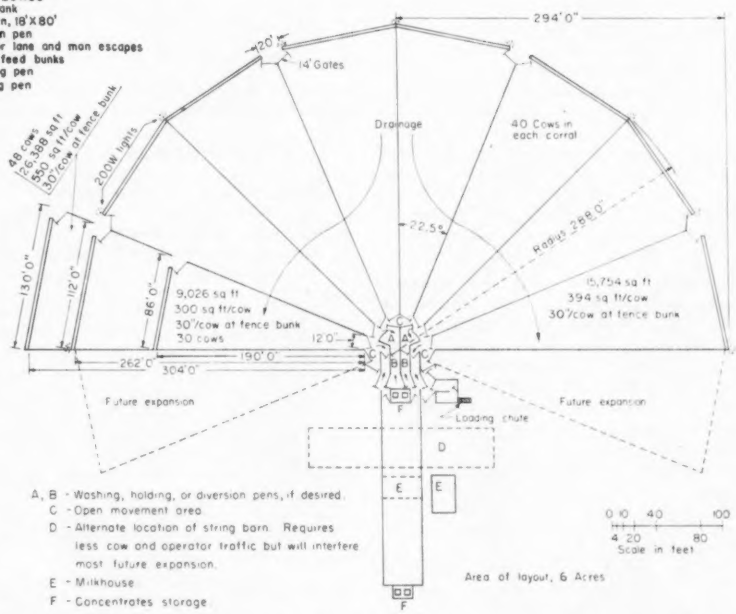

Fig. 2 *(Below)* **Pie-shaped corral layout showing relation to two possible locations of a string barn**

barns, respectively. Since holding and washing pens are used with elevated milking stalls and since the flow of cow traffic through the milking room should be continuous, the traffic system is more complicated than for string barns. Fig. 1 shows an arrangement for a minimum of operator traffic and gate manipulations. Details of how this works can be furnished on request.

Traffic between the corrals and a string barn is relatively simple. Only an open semicircular area at the narrow ends is needed between the corrals and milking barn (or washing, holding, or diversion pens, if any) as shown in Fig. 2.

Feed and Bedding Storages and Facilities

Fence feeding bunks on the perimeter are most convenient for all roughages. A minimum of 30 in. of linear space per cow is necessary at the feed bunks so all cows can eat at the tame time. Concentrates are usually fed while the cow is being milked, in the milking room or barn. Hay storage is also most convenient at the perimeter, outside the corrals, about 14 ft from fence bunks so feeding and other power equipment can pass.

Bedding storage is needed in cold climates. Shelters for both cows and bedding should be inside the corrals, with a minimum of about 45 sq ft per cow in the bedded area. If this shelter is open on a side away from the prevailing winter winds and can be opened on the other three sides, it may serve for summer shade (Fig. 3).

Weather Protection for Cows

Fence feed bunks may need protection from snow. An open shed or Dutch-barn type of structure can be used to cover the hay, feed passage for fence bunks, and an area 10 to 12 ft wide inside the corrals at the fence bunks to protect the feeding animals (Fig. 3). A structure 48 to 50 ft wide should be ample. If drifting snow is a problem, windbreaks connecting these structures may be necessary. Whether covered by a shelter or not, it is most important to have a strip of concrete at least 10 ft (preferably 12 ft) wide inside the corrals at the feed bunks and around water tanks to keep cows from mud during wet weather.

For prolonged periods of high temperatures, shades are not only advisable but necessary to prevent production losses. Shades of 40 to 50 sq ft per cow may be satisfactory, but it is better to have 50 to 60 sq ft. Width must be 16 ft, but 20 ft is better with 10 to 12-ft clearance to the plate for power equipment. If practical, the long axis is north to south so the early morning and late afternoon sun can reach all areas under the shade and dry up wet spots. Some tests have shown that hay is one of the most effective shade materials but has some disadvantages. Aluminum and galvanized steel are almost as effective, if the top is painted white and the underside black.

Corral Size

If the entire corral is paved, 225 sq ft per cow is usually ample. If there is paving only at the fence feed bunks, around water tanks and along fences between corrals, 275 to 300 sq ft per cow should be ample with good drainage. This amount of space is also satisfactory in the hotter climates if good shades are provided. If drainage is poor and there is paving only at the feed bunks and around water tanks, mud can be a serious problem even with as much as 400 sq ft per cow. Unpaved corrals must be well drained. In unpaved California corrals without a bedded area, it is common practice to build an earth mound in each corral from 5 to 6 ft high, slightly rounded on top, covered with 8 to 12 in. of some material such as sawdust, wood shavings, or rice hulls and large enough to allow 25 to 50 percent of the cows to lie down at one time.

Figs. 1, 2, and 3 illustrate corrals with 22.5 to 30 deg angles. In Fig. 2, cow capacities, area per cow, and total corral areas are shown for different sizes of corrals and how these features vary as the radii of the corrals vary. Fig. 4 shows an actual layout recently built in California. It can be expanded by continuing the corrals at both ends another 90 deg.

Milking Preparation Facilities

This paper is concerned with milking facilities only in their relationship to and ar-

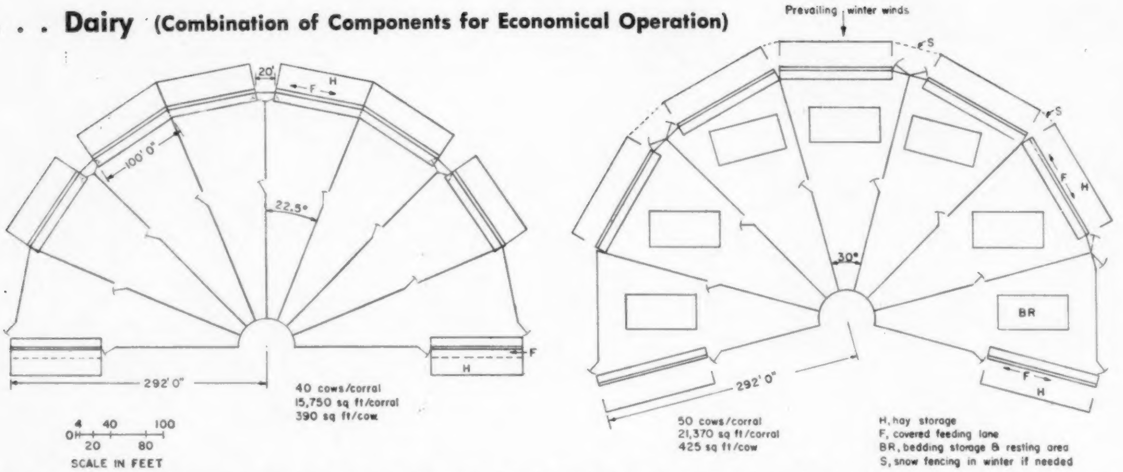

Fig. 3 Suggested pie-shaped corral layouts for cold climates that should give as much winter protection as L-shaped layouts commonly used for small herds. Corral capacity varies with the vertex angle if the length remains constant

rangement with pie-shape corrals. Any kind of milking barn or milking room works as well with a pie-shape layout as with rectangular corrals, or even better. Fig. 1 shows an elevated stall layout with pie-shape corrals and Fig. 2 shows a string barn layout.

Washing pens are used with elevated-stall layouts mostly in mild climates or warm weather, but a few string barns also use them. The type of washing pen is much the same for both types of milking layouts. Cows are not washed entirely clean in them but much of the dirt is washed off and the rest is soaked so that it is removed more easily and quickly in the milking stalls. This means that some cows will need additional washing in the milking stall before the udder is dried. Complete, satisfactory washing of cows can be done mechanically without further hand washing but so far only one such installation is known and it is homemade. Although cows may seem too crowded, from 14 to 15 sq ft of floor area per cow depending on breed size, is sufficient in the washing pen. Sprinkler heads in the washing pens are embedded in the concrete floor 3 ft apart in both directions. Spacings up to 4 ft in both directions have been found, but if the water pressure drops some cows may not be washed satisfactorily. Each sprinkler head is installed about 2 in. above the concrete floor and mortar placed around it to protect and support it. The mortar can be broken away easily if it is necessary to replace the head. Some dairymen think sprinkler action is better if sprinkler heads are staggered in alternate rows.

Although 15 sq ft per cow is usually enough for holding pens, 16 to 17 sq ft is not too much for hot climates. A roof over the holding pen will provide shade in the summer and protection from rain in the winter.

Figs. 1 and 2 indicate diversion pens for cows that need extra attention. These can be combined with hospital stalls and pens, or hospital sections can be provided elsewhere. If combined, they should be roofed and have weather protection on the walls. Fig. 1 shows a diversion pen only for the right side exit lane of the layout. A similar one is required on the left side. Fig. 2 also shows diversion pens in the open area at the center. Combining a loading chute with a diversion pen is an additional convenience.

Miscellaneous

With few exceptions, underfloor and underground drains are required for disposal of waste water from barn, holding pen, washing pen and milkroom. Barn and pen washings can sometimes be carried away in open concrete gutters to settling ponds or areas, or to the irrigation water. In most cases sludge traps are desirable or necessary to prevent clogging of drains.

Pie-shape corrals are usually satisfactorily lighted by 200-watt flood lights with built-in reflectors, mounted on 10 to 15-ft poles at the junction of the perimeter feed bunks and corral fences. Lights at the milking barn or washing and holding pens light the other end of the corrals.

Man escapes should not be overlooked; they save effort and steps, are a great convenience, and occasionally are a safety feature. For most operators 12 to 14 in. of clearance is ample.

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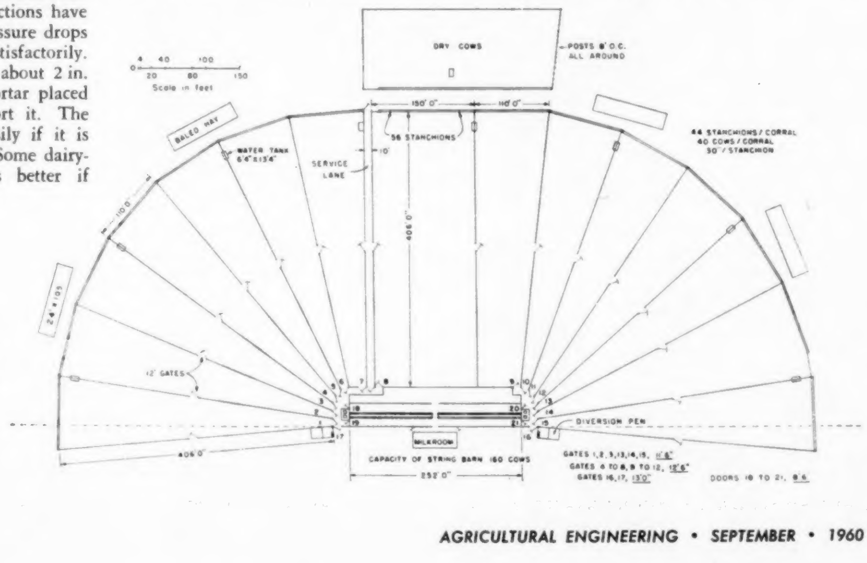

Fig. 4 Actual pie-shaped corral layout recently built in California. It can be expanded by continuing the corrals at both ends another 90 deg

BEEF

The Changing Beef-Producing Industry

Albert E. Darlow

AN attempt to predict the future of any business, particularly one as dynamic as beef cattle, is a rather hazardous undertaking. The chief alleviating circumstance is that few people will pay attention to what is said now — and still fewer will remember a few years hence that anything was said at all.

It does not seem necessary to go into detail on human population predictions since these are available to all of us, but I will itemize a few of the changes that I believe are ahead in beef cattle production.

The first change is that the number of beef cattle will increase. This will result from a continuing increase in human population; however, beef cattle numbers will increase at a relatively greater rate than will human population. This will come about because we are now, and will continue for some time, upgrading our diet with an inclusion of greater amounts of animal protein which will include, in particular, greater amounts of red meat.

The U. S. Department of Agriculture, in a recent publication, indicates that the demand for red meat between 1958 and 1975 will increase by something over 60 percent. Today we are consuming 80 to 85 pounds of beef per capita. Within the red meat area, beef consumption will continue to increase more rapidly than will consumption of other red meats. This has been true in the immediate past and will continue at least for a time in the future. Therefore, we can be sure we are going to have more beef cattle in the United States than we have now and we will probably have more in proportion to the human population.

Dr. P. H. Stevens, director of research, Farm Credit Administration, states that an average of 24 to 26 calves born per 100 human population has been the range in the past. This ratio may change in the future, particularly if animals go to market at a younger age and lighter weights.

Within the beef cattle industry, I am predicting there will be a great deal more attention given to what is now called "performance testing," whereby the heritable productivity of beef animals is estimated and measured. This need not be a separate organization for registering animals of all breeds that make certain gains under certain conditions. It can be accomplished within existing breed associations.

I believe this type of record keeping will gain because producers of commercial cattle will insist in the future on additional information about the bulls they buy and, as a result, the producer of purebreds will make this information available. It is just as logical that this information be made available as it is that milk production be measured or that the egg-laying ability of strains of chickens be determined. The question is not whether or not there be performance testing, but whether or not the testing will be supported and guided by established breed registry associations or by an organization completely outside the recognized breed promotion organizations.

As production testing work increases in our cow-calf operations, there will be need for additional equipment, such as improved facilities for handling and sorting, facilities for handling breeding groups, and other areas where the agricultural engineer can and must play a vital role. This is particularly true where artificial insemination is to be practiced with a minimum of time, expense and labor.

If we are going to have more cattle, the next question is: where are we going to put them? My third prediction, therefore, is that there will be a further adjustment in beef-cattle population within certain areas of the United States. I cannot be quite as dogmatic in this regard as I have been about the first two propositions and say just what the increase in population will be by areas, but certainly we can expect a shift in beef-cattle population.

Cattle numbers in several of the southeastern states have increased 300 percent in the past ten years. Last year the southeastern states showed an increase of 1,896,000 head of cows and calves over the previous year. In contrast, the eleven western states (traditionally the center of the beef business) showed an increase of only 923,000 head for the same period.

Take cattle feeding, for example. California shows nearly 700 percent more cattle and calves on feed last year than in 1930. Today they handle nearly 8 percent of all feeder cattle in the United States. Iowa handles 21 percent of all cattle fed out in this country, but the numbers on feed in Iowa have gone up only 127 percent since 1930, compared to the above figure for California.

Of course this shift in cattle fattening has been initiated by population to a great extent. We have seen the Gulf Coast states and the West Coast become greater consumers of beef, particularly of lighter weight beef of lower grades.

I would suggest that in the native grass area cattle numbers will not change much from the present high. The carrying capacity of this area is determined by rainfall or feed supplies. During the past few good years, the grass was about as good as it can be expected to be, at least for the next ten or fifteen years.

However, in those areas where beef cattle are not restricted to native grass and improved pastures can be used, an increase in numbers may be expected. The further increase in beef cattle in the southeast will be at a slower rate than it has been in the past. I see nothing in the future that would subsidize the southeasterners into cattle production, such as restricted cotton acreage and price supports has done in the past twenty or thirty years.

I think many of the folks in the Southeast who are now in the cattle business would presently be in the cotton business if they had not been, in effect, forced out of it. Now that they've been in the beef cattle business, they have decided that it is good; they like it, so they will stay. However, the big flush may be over and further increases in the Southeast may be at a more moderate rate. Incidentally, another thing that helped in the past few years to swell cattle population in the Southeast was the drought in the Southwest.

I feel that, when we are no longer producing wheat for government storage, the price will inevitably be much lower than it is today and the range and wheat country will carry more cattle because land that is now in wheat will be put into permanent grass or forage of some kind. I am indicating that the government program on wheat has held down cattle numbers in the West, and the government program on cotton has resulted in a vast increase of cattle numbers in the Southeast. I think this is irrefutable. What the government programs will be in the future, of course, I have no way of knowing. Whatever they are they will of course have some influence on many things other than cattle numbers and will need to be taken into consideration. The effect of such programs in shifting cattle population is problematical.

I am suggesting that part of this increased population will be in the farming states. When it is no longer profitable to grow corn for government storage, when the time comes that our excess of feed grain must be used or the acres now in feed grain be diverted, then some of the acres now growing corn grain will be utilized for growing forage. It has already been shown by Michigan and other states that proper preparation of corn by ensiling the whole plant will increase the carrying capacity of a given area of land by 50 percent. Then, in those areas where the soil fertility is good and the climate is such that high crop yields can be obtained, there will be an increase in numbers of cattle. This,

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of course, could be true also of the Southeast. Most of the cattle that have gone into the Southeast are on pasture, not on silage or a fattening program.

While considering cow herds, one other change that seems certain is that there will be more carrying of feed to the cattle, and less of cattle going to the pasture to harvest it themselves. Again I am not talking about the traditional cow-calf areas of the Great Plains, but rather the farming areas where carrying capacity can be increased by field harvesting of green forage in the summer and hauling it to cattle rather than letting them graze it. Also, the wintering program may be changed materially in some areas from that followed at the present time. Some of these changes, of course, will be delayed until such time as the price-cost squeeze forces people into making adjustments.

Whatever the changes, and whenever they are made, I predict that there will be more processed feed fed to cattle in the future than in the past. By "processed" I don't mean concentrates alone. There will be more pelleted feeds, wafers, or whatever proves to be the best. More silage will be used and whatever is fed will be the result of mechanization as far as processing and feeding are concerned.

Twenty years ago I suggested that all farming operations in the planning stage have the central idea of labor-saving devices in mind — whether it be in machinery, feed-lot arrangement, barn structure, or what not. I think this is becoming increasingly important. Reduction of labor can be accomplished only when the necessary operations are accomplished by mechanization and power.

If there are going to be more cattle produced and more beef consumed, this means in my opinion, more cattle will go into, and out of, the feedlots each year. Three or four questions immediately arise. Where will the feedlots be? Who will operate them? How large should they be and what are we going to feed the cattle? Of course, I have no crystal ball into which I can put questions and get answers, but some of these ideas I hope are worth passing on.

One is that there will be more feeding done in the areas that have traditionally been producing feeder cattle. I have already indicated that I think there may be more cows in the Corn Belt. By the same token, I think there will be more feeding in what we now call the "cow country." As the population in the south, southwest, and west increases, it will become increasingly ridiculous to grow cattle in the southwest, ship them to the north to be fed, and back to the southwest for consumption.

So as I see it, there will be an increase in feeding in the range states. In these areas, I believe the pattern will be one of large operations. There is no tradition in this area of farmer-feeders as in the midwest, and there is still a reluctance on the part of the farmer or rancher to go into cattle fattening. So I am predicting that in the range states the feeding operations will be on a large scale on a cost-of-feed plus pen-rental basis. By that I mean hundreds or thousands of cattle in the feed yard at any one time, and certainly several thousand passing through the feed yard each year.

One of the chief reasons that this feeding will take place is that low-cost grain is now available. Grain sorghum, particularly the hybrid varieties, now makes very high yields under irrigation. It will be increasingly fed at home by large feed operators. I am not predicting that this extremely large feed yard will be typical of the entire United States, but I think it will be rather typical of the plains states and the southwest. Of necessity these feed yards, and all the feed-handling facilities, will be completely mechanized and as automatic as possible, making it possible for one man to feed several hundred head of cattle each day.

As feeding operations get larger, the overhead cost of producing a pound of beef becomes smaller. Anything that will change the utilization of feed will greatly affect the profit picture, because 85 percent of the total cost of fattening a beef animal (not counting the cost of the animal itself) is the cost of feed itself.

Recent Arizona studies show that, if you have 500 head of cattle or less on feed, it will cost you about $1.34 for each hundred pounds of gain just to pay for labor, equipment and other non-feed costs.

If you have 2,500 head, the cost per 100 pounds of gain drops to $1.02, while if you have 12,500 head on feed it costs you only 57 cents per 100 pounds of gain as non-feed cost. So we see that operations have of necessity become larger and almost completely mechanized in many instances to cut per unit costs.

In traditional areas of cattle feeding, I anticipate that operations also will be enlarged as they have been in the past, but I anticipate the growth will be more gradual and in line with the general growth of farms. Thus we will still have feeders who handle only a few head as a means of using labor during the winter and provide a market for feed.

I feel that the individual who has been feeding two or three carloads of cattle and carrying the corn to the cattle in a basket, so to speak, is a thing of the past.

The middle-sized operator may disappear and the two types left will be the small feeder and the one who feeds enough cattle so he can afford to install the necessary machinery for storing, handling, mixing, processing and distributing the feed to the cattle. How many cattle this latter will require I do not know, but I am convinced that all of the feeding will be mechanized.

Whether cattle on feed will get more or less roughage than they have had in the past is a question. We have been much interested in work that has been done at Missouri and elsewhere, indicating that choice cattle can be produced on a very much lower percentage of roughage than currently used. Recent reports show that some experimental cattle were fed no roughage at all. So, in the future, I would say that fattening cattle may receive less grain than they have in the past.

One of the advantages of more concentrated rations is that less feed is needed in a concentrate-roughage ratio of five to one (five times more concentrates than roughage); the cattle actually need 20 percent less total feed to produce a pound of gain as compared to 60:40 ratios now being fed. This would mean the saving of 12 tons of feed in the daily operation of a 5,000-head feedlot.

Whether the grain will be pelleted along with protein supplements, minerals, etc., or whether it will be ground, crushed, or rolled, I do not know. Whether the hay will be fed long, chopped or ground and pelleted again, I'm not sure. In different areas and in different feeding operations, it may be possible to find each of these types of roughage, as well as different preparations of grain. I feel quite certain that in areas where it is possible to produce it, silage will play an increasing role in the feedlots.

In the West I can see there will be some integrated operations from the feeder-calf stage on. I do not anticipate there will be a great deal of integration, such as some outfit owning the land, running the cows, producing the calves and feeding them out — even to the point of slaughtering, processing and distributing the meat.

I think there will be some operators, however, who will buy cattle to go on feed, slaughter the cattle and sell the carcasses. However, I am not anticipating that this will be the pattern. I think, in the large operations particularly, some means will be developed whereby the feeder of large numbers of cattle has a guaranteed outlet for his beef. However, he probably will not feed them on contract, as we think of it now. The change in the market pattern of livestock as it relates to terminal markets indicates that the operator who is feeding thousands of cattle will, of necessity, have some guaranteed outlet.

So there is much in this changing beef industry to interest the agricultural engineer. It seems to me that it is quite important, in addition to helping the animal scientist plan research work, that the agricultural engineer will be doing a great deal of his own research work. He must be particularly vigilant in watching the results of feeding tests in order to keep up on current thinking as to latest developments. In other words, he must be in position to design machinery to produce and deliver the kind of feed that the animal feeding expert decides is the most economical ration to feed.

In some instances, I think the agricultural engineer will need to get over and stir about not only as an assistant in the animal science area, but prod a few of the folks who may be a little bound by tradition as to how things should be done. Prodding from an outsider might result in new research and new breakthroughs in the general field of animal production.

Effects of Thermal Environment on Beef Cattle

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Fellow ASAE

BASIC information on how thermal environment affects beef cattle in growth rate, efficiency of use of feed, water consumption, and heat and moisture production is slowly becoming adequate for correct design of physical facilities. The data included in this paper are largely from references cited by Nelson (9)* for the ASAE Technical Advisory Committee on Plant and Animal Husbandry and in the compilation by Kelly (6) for the ASAE Technical Data Committee in *Agricultural Engineers Yearbook*.

Growth Rate, Feed Utilization, and Heat Tolerance

The producer is interested first in the effect of thermal environment on rate of gain and utilization of feed. The optimum environmental temperature for beef cattle varies with breed, age, weight, and condition. In discussing European breeds, Guilbert and Hart (5) said that "an average monthly temperature of 75F may be considered about the upper limit for an extended period that does not result in depressive effects."

Brody (1) found that "the heat tolerance differences between European and Indian cattle, up to 95 F, is about 20 deg. The 'comfort zone' (temperature interval during which no demands are made on the temperature-regulating mechanisms) of European cattle is between 20 and 60 F, for Indian cattle between 50 and 80 F."

Rhoad (12), in developing a scale of heat tolerance for cattle (based on deviation of body temperature from the normal), ranked the breeds as follows:

Brahman	93
Braham ½, Angus ½	89
Santa Gertrudis	82
Brahman ¼, Angus ¾	76
Hereford (grade)	73
Aberdeen Angus (purebred)	56

One of the few "farm type" investigations of the effect of ambient temperature on rate of growth of beef cattle was by Ragsdale *et al* (11). They measured the reactions of three breeds — Shorthorn, Brahman, and Santa Gertrudis — to two constant temperatures, 50 and 80 F. Air velocity in the laboratories was about 50 fpm; relative humidity was 62 percent in a 50 F chamber and 54 percent in an 80 F chamber. Illumination was continuous by one 40-watt incandescent bulb, and six 200-watt incandescent bulbs were added between 6 a.m. and 6 p.m. Control animals were maintained in an open shed.

Fig. 1 shows the effect of the two temperatures on the growth rate and feed utilization of Shorthorns in three age ranges — 3 to 6, 6 to 12, and 12 to 15 months. The weights of the animals, fairly uniform at the start of the experiment, quickly became disparate. The calves at 50 F grew much more rapidly so that the yearling groups (12 to 15 months) are not comparable as to weight. The benefits of the lower temperature are nevertheless very apparent.

The effect of temperatures below 50 F are not available.

Total Heat Production

Total heat production is influenced by thermal environment, animal breed, condition, age, weight, and plane of nutrition. Studies by Forbes *et al* (3, 4) and Kibler (7) were used in constructing the curves of Fig. 2. All animals were Shorthorns. The Forbes investigations were concerned with the effect of plane of nutrition on heat production at a constant temperature of about 64 F (curves A and B). Plane of nutrition ranged from fasting to three times maintenance ration. The rations were made up of corn meal and alfalfa hay. At the "maintenance" level, heat production increased by about 17 percent when hay only was fed. Among other things, the Kibler studies (curves C and D) related animal weight to heat production at two constant environmental temperatures, 50 and 80 F. These animals, also fed corn and hay, were on full feed, probably two to two and one-half times the maintenance ration used by Forbes *et al.*

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*Numbers in parentheses refer to the appended references.

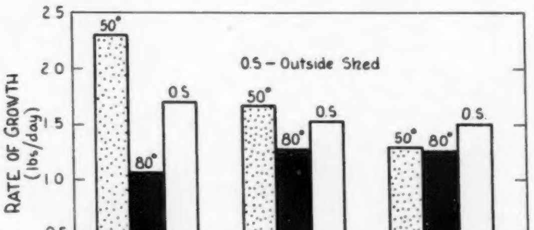

Fig. 1 Rate of growth and feed utilization of Shorthorns in three age ranges, 3 to 6, 6 to 12, and 12 to 15 months, and at two environmental temperatures, 50 and 80 F

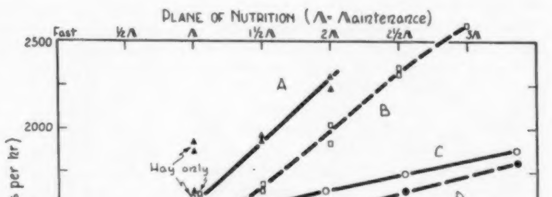

Fig. 2 Effect of plane of nutrition and animal weight on total heat production of Shorthorns. (Note environmental temperature given for each curve)

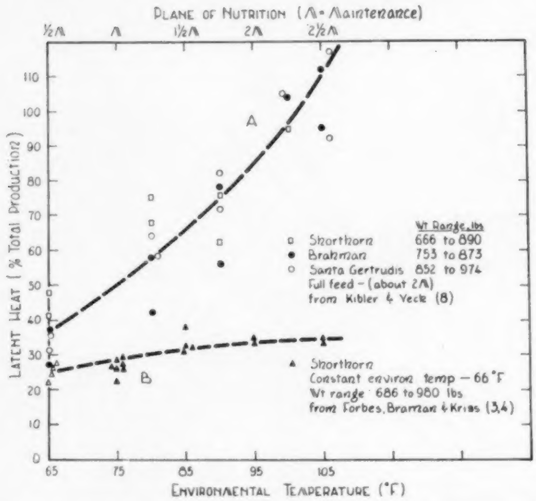

Fig. 3 Effect of plane of nutrition (curve A) and environmental temperature (curve B), on percent latent heat production. (Note animal weights given for each curve)

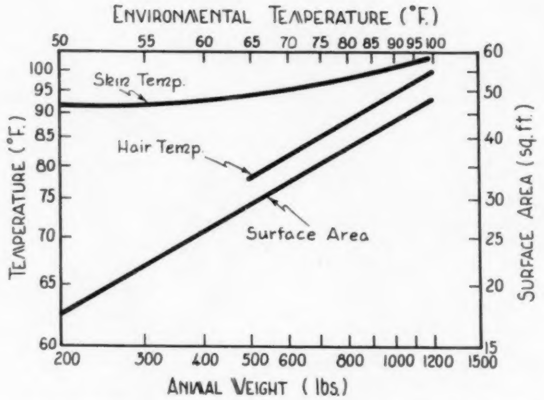

Fig. 4 Effect of environmental temperature and animal weight upon skin and hair temperatures, and surface area, of beef cattle. (see text)

Latent Heat

The amount of heat lost by vaporization is important because it is less readily available for heating incoming cold air and also presents a more difficult cooling problem in areas of high temperature. Factors affecting the proportion of the total heat lost as vapor are: age, weight, condition and breed of animal, mean radiant temperature, ambient temperature and relative humidity, air motion, and plane of nutrition. Fig. 3 shows the percentage of total heat lost as vapor from both skin and lungs for (upper curve) three breeds – Shorthorn, Brahman, and Santa Gertrudis – at ambient temperatures between 65 and 106 F, as measured by Kibler and Yeck (8). Before the measurements the animals had been kept for long periods at constant temperatures of 50 and 80 F. They were on full feed (about twice maintenance ration) of hay and grain. The weight ranges are indicated. It is to be noted that at 100 F and above the amount of heat lost as vapor is greater than the heat produced, indicating that the animal is actually gaining heat by other methods. The lower curve, adapted from the work of Forbes *et al* (3, 4), relates percent latent heat to plane of nutrition, with a maintenance ration of ground corn and alfalfa hay as the point of reference. Since the latter tests were at a constant calorimeter temperature of 64 F and the rations for the tests of curve A are equivalent to about twice maintenance ration, the two curves correspond very well.

Surface Temperature

Surface temperatures of animals largely determine heat loss by radiation and convection and may also be an indication of comfort or tolerance to temperature extremes, both hot and cold. The Missouri experiments referred to before (13) showed that, at 80 F constant temperature, increasing body weight was associated with decreasing skin temperature and increasing hair temperature. At 50 F, both skin and hair temperatures decreased with increasing weight. The measurements in Fig. 4 are averaged for Shorthorn, Brahman, and Santa Gertrudis calves of 750 to 900 lb at 50 to 100 F (13). Also given is the relation between animal live weight and surface area, by Brody *et al* (2).

Ventilation

Open or semi-open beef shelters with no air conditioning are usually considered to have adequate circulation of air. The Committee on Housing of Beef Cattle and Sheep states (10): "Closed barns are not recommended in most areas and for most systems of production. Where this type of barn is used, it will usually be closed for only short periods, and, for this reason, there will be little need for a complete ventilating system. It is necessary, however, to remove moist, foul air from occupied buildings that are closed for longer periods. For this purpose, one or more electric fans may be used, or circulation may be provided by a system of inlet and outlet ducts. . . . Fans should circulate about 3,000 cu ft of fresh air per hour per animal; the ventilating area provided by the ducts should be about 30 sq in. per head."

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Basic Requirements for Beef Cattle Housing, Feeding and Handling

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THE design of beef cattle housing and the associated feeding and handling system requires the adapting of basic design criteria to the individual feed-lot conditions of climate, surface terrain, feeding system and management. The design selected must provide the necessary feedlot, housing, feeding, watering, feed storage and processing, waste disposal and livestock-handling facilities. Besides providing for the necessary basic facilities, the designer must organize these facilities for efficiency of feeding, ease of handling, economy of labor and efficient use of capital.

The data and design criteria that follow are presented as an aid to making individual designs. The minimum design criteria listed in this paper are not adequate wherever extreme conditions exist.

Published data based on qualified research in many areas of the basic requirements for the planning of shelter, feedlots, feeding and watering of beef cattle are definitely lacking. Where no source of data is cited, the following data are based on field observations of installed beef cattle management systems.

Feedlot Areas. Provide for two or more individual lots to permit separating cattle by age, size or sex. Limit the lot size to 100 to 125 cattle for normal size of operations. Individual feedlot areas to accommodate up to 200 head each will reduce costs and simplify layout design in large scale beef production units (1)*. Either natural or artificial drainage must be provided. The area of feedlot provided per animal, rainfall, slope and soil type will materially affect the need for supplemental drainage and for the hard surfacing of lots.

Shed Space. Cold weather conditions have not been shown experimentally to have detrimental effects on beef cattle. However, wind velocity and direction, snow deposits and potential drifting, winter rains and other cold weather phenomena must be given primary design consideration. In northern areas, orient all buildings to provide maximum protection from winter winds. Use sheds with at least one open side in all areas to insure adequate ventilation.

*Minimum Floor Area of Shed Space (where required)**

Cattle to 600 lb weight – 15 to 25 sq ft per animal
Cattle above 600 lb weight – 20 to 35 sq ft per animal
Mature cows – 30 to 50 sq ft per animal

*Use the smaller figure under dry or moderate climate conditions. Use the larger figure in areas of winter rains or other severe weather conditions.

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*Numbers in parentheses refer to the appended references.

TABLE 1. RECOMMENDED FEEDLOT AREAS

Feedlot condition	Minimum area per animal
Not hard surfaced, good drainage on medium to light-textured soil	200 to 300 sq ft
Not hard surfaced, average or poor drainage on heavy soils*	300 to 400 sq ft
Hard-surfaced portland cement† or asphaltic‡ concrete (slope minimum of 1/16 in. per foot). Recommended slope 1/4 to 1/2 in. per foot)	50 to 70 sq ft§

*Unsurfaced feedlots normally cannot be kept firm in areas of heavy soil (clay loam or finer) and in areas with poor drainage except under very low rainfall conditions.

†Four-inch thick portland cement concrete is adequate for areas not subject to travel by heavy equipment. Six-inch-thick portland cement concrete is required where heavy equipment will be used.

‡Hot-mix, hot-laid asphaltic concrete made from good quality aggregate and straight asphalt cement is required for the surface course. Consult local authorities for approved base, sub-base, sealing and compaction requirements.

§Include shelter space where it has hard-surfaced floor.

Shade. Hot weather seems to have more effect on beef cattle than does cold weather (2). Provide 30 to 40 sq ft of covered shade area per animal to protect against high summer temperatures. Construct the shades with 10 to 12 ft of clear height (3) and orient on a north-south axis.

Feeding Equipment. The requirements for feeding equipment will be influenced by the size of animal, the frequency of feeding and the type and quantity of feed fed. Space must be provided for all of the cattle to feed at one time whenever feed is not available for the cattle at all times.

Daily Feed Requirements. This summary of data on feed requirements is presented only as a guide to the engineer in planning required feed storage, processing and handling for a beef enterprise. It is not presented as the basis for determining feeding rations. When available, the exact daily and total ration or rations to be fed should always be used as the basis for designing feeding, feed storage, processing and handling facilities.

The feed requirements of beef cattle can be expressed as a percentage of the animals' live weight. The general daily feed requirements for representative classes of beef cattle are shown in Table 4. The total amount of air-dry feed eaten per 100 lb of live weight decreases as the animal weight increases. Older cattle and more fleshy individuals consume less feed per unit of body weight than do younger animals carrying less condition. Fleshy beef bulls weighing over 1,800 lb, for example, will consume feed in amounts equal to 1.5 percent of their live weight, whereas thin steers less than two years of age will consume fully twice as much feed per unit of live weight. Therefore, in all instances, the higher percentages shown in Table 4 apply to the lighter cattle.

Grain and air-dry roughage are interchangeable on a pound for pound basis for cattle that are fed at least one-half of a minimum full feed of grain (1.5 lb daily per 100 lb of live weight) including the grain in any corn silage that is fed (4).

TABLE 2. MINIMUM LENGTH OF FEED BUNKS

	Minimum lineal inches of bunk space per animal
Not self-fed (cattle under 600 lb)*	18
Not self-fed (cattle over 600 lb)	24
Not self-fed, mature cows	28
Self-fed†	
From portable bunks	10 to 12
High roughage ration (more than one-half of ration hay-silage or equivalent)	4 to 6
High grain or all grain ration	3 to 4

*Not self-fed is considered to be any system of feeding where all of the cattle in a lot will feed at one time.

†Self-fed is considered to be any system of feeding where cattle will have feed available at all times.

TABLE 3. MAXIMUM DIMENSIONS OF FEED BUNKS

Feed bunk height, ground to top of bunk sides (cattle under 600 lb weight)	22 in.
Feed bunk height, ground to top of bunk sides (cattle over 600 lb weight)	24 in.
Feed bunk width (fenceline bunks)	30 in. (at bottom of bunk)
Portable or mechanized feed bunk width, not divided*	40 in.
Portable or mechanized feed bunk width, divided in center	60 in.

*Feeding on both sides of portable bunks. Use fenceline bunk dimensions where cattle will feed on one side only.

TABLE 4. DAILY FEED REQUIREMENTS FOR REPRESENTATIVE CLASSES OF BEEF ANIMALS (5)(6)

Class of cattle	Daily feed requirements (air-dry basis) as percent of body weight
Fattening cattle	3.0 to 2.5
Wintering weanling calves, 400 to 600 lb	2.75 to 2.5
Wintering yearling cattle, 600 to 900 lb	2.67 to 2.0
Wintering pregnant heifers, 700 to 1,000 lb	2.7 to 1.8
Wintering mature pregnant cows*	1.5 to 1.8
Cows nursing calves, first 3 to 4 months postpartum	28 lb daily
Normal growth heifers and steers, 400 to 1,000 lb	3.0 to 2.1
Bulls, growth and maintenance; moderate activity (600 to 1,800 lb)	2.67 to 1.5

*Under some range conditions it may not be economical to feed pregnant cows during winter months at this level of total feed as short periods of weight loss can be tolerated without serious effects.

The ration fed will frequently change from the rations originally planned. The exact ration to be fed will frequently be unknown. When these conditions exist, two-thirds of the ration of fattening cattle should be concentrates (grain or equivalent plus protein) and one-third roughage (hay or equivalent — 3 lb of silage to equal 1 lb of hay). For cattle on maintenance (mature cows or bulls) fifteen parts should be roughage and one part concentrate, and for wintering for normal growth of heifers or steers ten parts should be roughage and one part concentrate. Except for fattening cattle, concentrates can be eliminated when the roughage is a good quality legume.

Feed Storage and Processing Facilities. Required feed storage facilities will vary, depending on the source and availability of the feeds. Provide storage for all feeds produced on the farm. Consider local or regional market conditions, evaluation of cost-benefit ratios of required storage and equipment as against feed costs and convenience and reliability of feed supplies when considering the need for and the design of feed storage facilities for purchased feeds.

Give the following facts primary consideration in the design of storage, processing and feeding facilities for a beef enterprise. The material which requires the most handling time per ton in order of magnitude are: ground feed, bedding and hay. The general type of operations requiring greatest handling time are: feeding or distributing, removal from storage, and moving from storage to area of use. Consideration of average annual tonnages involved along with man-hours per ton reveals that the materials requiring the most total annual time in order of magnitude are ground feed, silage, manure and hay (7).

Information on the weight of silage is shown in tables 10 and 11. Information on the average weight of other feed materials is shown on page 593 of this issue.

Water Requirements. Water intake of cattle is a combined function of dry matter consumption and temperature, except for lactating cattle where an allowance must be added for the milk produced. Milk is estimated to be 87 percent water by weight. The total daily water intake of beef cattle is shown in Tables 5 and 6. The moisture in the feed can be ignored in calculating total water requirements when the ration consists of hay, grain and similar dry feeds that are about 10 percent moisture. The moisture in succulent feeds such as grasses or silage must be subtracted from the total water intake when calculating the water supply requirements of beef cattle. Temperature has little or no effect on water intake rates between 10 and 40 F. Rations with a high salt content will increase water requirements significantly.

For design purposes, where the specific rations to be fed are not available, 12 gal of water per day per animal should be provided in temperate areas (5). Provide 20 gal per day per animal in subtropic areas. Assume an 8-hr per day duty cycle for the pumping equipment. Where wells with limited water supplies must be used, install large storage tanks with a capacity of at least one day's water requirement. Similar size, large storage tanks, or multiple interconnected wells with individual water systems, are desirable for large feeding installations. A storage tank with a capacity of three day's water requirement is usually large enough to provide fire protection along with additional storage for livestock.

Water Equipment

In confined feedlots: automatic waterer (heated in northern area) approximately 80 head per foot of water trough length.

Range or open pasture conditions: 3 to 4 lineal inches of watering tank perimeter per head in a herd watering at one time.

Manure Production and Handling. Under farm conditions the term "manure" refers to both the excrement and the bedding. The quantity of manure produced depends so much upon the character and amount of feed eaten and the character and amount of bedding used that it is difficult to give an accurate figure for either daily or yearly manure production. Two sets of figures are shown. There is a lack of agreement between these two sets of data, illustrating that the system of management used in a beef enterprise will greatly influence the amount of manure produced. Table 7 shows the total excrement per day when various rations are fed. The data shown in Table 7 can be added to the daily weight of bedding used to arrive at an estimated weight of total daily manure produced. All figures shown assume a concrete floor in the area where the manure is accumulated and does not allow for evaporation, oxidation or other losses of weight. Approximately 15 percent less (8) manure will be recovered from dirt-floored areas than from concrete manure-accumulation areas.

Table 8 is another set of data which shows the actual weight of manure accumulated where the shed was well bedded and both the shed floor and adjoining lots were paved.

Manure resulting from beef cattle operations is normally moved and disposed of in

TABLE 5. TOTAL DAILY WATER INTAKE OF BEEF CATTLE (8)

Temperature, degrees F	10 to 40	50	60	70	80	90
Gallons of water per pound of dry matter consumed	0.37	0.40	0.46	0.54	0.62	0.88

*Total water intake includes both water drank and that contained in the food.

TABLE 6. WATER REQUIREMENTS OF COWS NURSING CALVES FIRST 3 TO 4 MONTHS AFTER PARTURITION (7)

Body weight, lb	Expected daily gain	Dry matter daily: 70 F and below	80 F	90 F	Temperature, deg F (Gallons of Water*): 10 to 40	50	60	70	80	90
900-1100	0.0	25.0	22.8	16.8	11.4	12.6	14.5	16.9	17.9	16.2

*Total water intake includes both water drank and that contained in the food.

TABLE 7. EFFECT OF CHARACTER OF RATION ON AMOUNT OF MANURE PRODUCED (10)

Ratio of hay to corn to linseed meal	Average feces per day: Maintenance, lb	Full-fed, lb	Average, lb	Average urine per day: Maintenance, lb	Full-fed, lb	Average, lb	Total excrement per day: Maintenance, lb	Full-fed, lb	Average, lb
1:1:0	19.2	57.1	38.4	9.0	12.0	9.7	28.2	69.1	48.1
1:3:0	11.0	44.2	27.3	10.8	13.1	11.7	21.8	57.3	39.0
1:5:0	8.5	26.7	18.0	5.6	8.0	9.0	14.1	34.7	27.0
1:4:1	7.7	22.3	15.8	6.6	14.3	10.2	14.3	36.6	26.0

the solid or semi-solid condition by conventional manure-handling equipment. No data are available comparing the handling of manure from a beef cattle operation in a liquid or semiliquid as against solid or semisolid condition. Table 9 shows the labor required for handling manure.

Feed and Handling Alleys. Provide a 12-ft minimum clear width for all alleys for feeding or moving and sorting cattle. However, adapt all alley widths to special requirements for livestock and materials handling. Always provide handling alleys separate from feeding alleys in all installations where large numbers of cattle are fed or where cattle will be moved regularly or frequently.

Feedlot Fences, Working Corrals and Livestock - Handling Equipment. Properly constructed wire fences (12) are adequate for pasture fencing. Construct all fencing for feedlots, corral or livestock handling areas from two-inch or full-dimension one-inch boards or steel cable. Build all feedlot line fences at least 5 ft high. Build working corral fences at least 6 ft high (13). Space the posts no more than 10 ft apart for feedlot line fences and 8 ft apart for corral working fences and solid fence windbreaks.

Individual feedlot layout and requirements will determine the design of corral arrangements and the selection of the necessary handling equipment. Working corrals can be designed best by referring to a selection of complete layouts (13).

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TABLE 8. MANURE OBTAINED FROM CATTLE FED ON PAVED FLOOR IN OPEN SHED AND ADJOINING PAVED LOT (11)

	Number of lots averaged	Average days fed	Average manure per head: Total period (tons)	Average manure per head: Per month (tons)
Calves				
Full fed with silage	29	229	1.82	0.23
Full fed with dry roughage	10	235	2.18	0.30
Full fed with ear corn silage	8	231	2.16	0.28
Wintered without grain	5	132	1.59	0.36
Yearlings				
Fed over 140 days	4	150	2.24	0.45
Fed under 101 days	11	91	1.52	0.51
Dry beef cows	4	134	2.91	0.66

TABLE 9. MAN HOURS PER TON FOR HANDLING MANURE FOR BEEF CATTLE (11)

Operation and method	No. of farms	Average tons per year	Average man-hours per ton
Removal from stable	—	—	0.18
Manual	1	80	1.00
Mechanized	15	767	0.13
Transporting to pile	—	—	0.02
Eliminated	15	767	0.00
Semi-mechanized	1	80	0.25
Loading into spreader	—	—	0.02
Mechanized	1	80	0.25
Automatic	15	767	0.00
Total	16	724	0.22

TABLE 10. CAPACITY OF TOWER SILOS IN TONS OF CORN SILAGE (14) (68 TO 72 PERCENT MOISTURE†)

Avg. weight per cu ft	Depth, ft	Diameter, ft: 12	14	16	18	20	22	24	26	28	30
44	30	75	102	133							
47	40	106	145	189	239	295	357	425	499	579	665
49	50	138	189	246	311	385	466	554	650	755	866
51	60		236	308	389	480	581	692	812	942	1082
53	70‡			373	471	582	705	838	985	1143	1311
55	80‡					691	836	994	1168	1355	1515

†Grass silage as placed in the silo will vary both above and below these figures, depending on whether the grass is wilted or direct cut and on the composition of the forage.

‡Not recommended, added height requires more power for filling and more work for feeding out and/or maintenance.

TABLE 11. CAPACITY OF HORIZONTAL SILOS (15)

Corn or grass silage in a horizontal silo, well packed by tractor or animals weighs from 40 to 50 lb per cubic foot. The exact weight depends on the material, its moisture content, whether it is chopped or long, the fineness of chopping and the care with which it is packed.

Combining Components for Economical Beef Production

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THE authors of other papers in this issue on the subject of beef production have presented current and projected economic and geographic analyses of beef production, as well as the most advanced information available on the environmental and functional requirements of beef cattle housing and equipment. This paper will deal with combining the components for economical operation, which I have interpreted as the over-all design function in the development of a physical plant for a specific enterprise. No new data will be presented since the over-all designer is a consumer of basic engineering information, not a producer. His function is primarily the sorting and assembling of available components or parts.

As engineers, we all received training, and most of us have experience, in the per-

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formance of the design function. Recognizable steps in the development of any complex design include the following:

1 The collection of pertinent physical, economic, and personnel data on the specific project
2 The qualitative and quantitative analysis of these data
3 The preparation of preliminary studies of potential space organization, flow patterns, etc., and the exercise of judgment in their selection or rejection
4 The successive trial application of known available components and the further exercise of judgment in selection or rejection
5 The design or development of new parts or components if suitable developed units are not available
6 The capacity determination or sizing of components for proper integration or functional performance
7 The preparation and presentation of the completed design in the form of plans, specifications, and instructions, as required for the particular project and proposed method of assembly.

On large-scale engineered projects, such as public works, production plants, transportation systems, etc., common engineering practice involves the complete performance of each of the above design functions in meticulous detail, making use of all the specialized services and data available, including, in the case of production units, detailed information on the various production processes and the manpower and capital limitation imposed, with the management involved in, but actually delegating, most engineering decisions.

By contrast, the traditional concept of optimum land use through diversified crop production and the resulting diversified conversion of the raw material produced into livestock products has not been conducive to acceptance of the same complete engineering-design function in farmstead development. The producer has been, and is now, his own design engineer. A complete engineering-design service has not even been offered in this field.

With limited exceptions, the engineering services which now accompany the production, distribution, sale, and assembly or erection of the components, which make up a mechanized system for the handling of beef cattle, or for any other livestock, are concentrated on the development and production of the components, with the over-all design function delegated to the owner, dealer, contractor, or salesman.

Design information presented through the extension agricultural engineering services of the colleges or universities, and of the U. S. Department of Agriculture, the farm press and commercial organizations, and even the engineering information furnished with specific components is "do-it-yourself" information. These agencies or their engineering personnel do not actively assist in performing detailed over-all design of individual installations.

The planning and installation of a complete system is a far more complex engineering problem than the producer has previously encountered, not only from the strictly physical standpoint, but also from the standpoint of the economic and personnel factors involved. In over twenty years of experience in the design of agricultural experiment station facilities, which required complete engineering design because construction contracts were let by competitive bids, as well as in the design, as a private consultant, of individually owned facilities where the owners were willing to delegate the over-all planning function and pay for the service rendered, I have arrived at a firm conviction that few producers are competent to perform this function. Furthermore, it is a difficult task to force the basic management decisions involving economic and personnel considerations upon which a sound over-all engineering design may be based. A still more delicate operation is the "unmaking" of unsound management decisions, particularly where the producer suspects any bias on the part of the consultant.

How should this comprehensive design be accomplished? Existing engineering organizations are "spread too thin" to accomplish this work on an individual farm basis. Manufacturers and distributors of buildings and equipment or their components are aware that distributors cannot provide the service required, and are seeking new merchandizing methods. The producer, suddenly finding himself an industrialist, is equally confused. Our approach has been to superimpose, over existing engineering organizations and existing distribution systems, enough additional engineering service to "get by".

In our engineering training we were taught to proceed from initial data to a rational solution of an engineering problem. After we had mastered the rational solution, we were permitted to use formulas and hand-booked solutions, i.e., short-cut methods. Our current confusion appears to result from the attempted use of all of the short cuts without first mastering the rational solution. In the process, we have largely ignored, delegated, or attempted to standardize the first four steps in the engineering design, and have not fully performed the last three.

Many will contend that the producer, having always acted as his own design engineer, will not buy and pay for engineering design service. Neither has he previously bought and paid for complete livestock production systems. We must face the fact that over-all engineering design is even more vital to the success of the installation and of the enterprise than is the engineering of the component parts. We must develop the organization, personnel, and facilities to perform this function well, and then insist that the package offered include the design service required. The contention that the producer will reject such service because of tradition is invalid, since the situation is too new to have acquired tradition. If we, as a group representing a large portion of the engineers and manufacturers involved, act promptly and decisively to force recognition of complete design as a standard procedure, the producer will accept the service and consider it a necessary economy.

The only guarantee of success in this approach is that it is working in other engineering fields. A drastic overhaul of the engineering services now available to agriculture, the training of many new design engineers, and a complete revision of the engineering services offered with the sale of building and equipment components would be needed.

Having once entered the field of complete engineering design, we would undoubtedly find that parts of certain design steps are essentially repetitive — that certain short cuts may be permissible. New techniques and devices, such as computers, models, and linear programming, may be used in the performance of the second, third, and fourth steps (1)* to improve performance and accuracy, or reduce the cost of design. Economists, farm managers, nutritionists, and other specialists may be better able than we to perform some design functions. If so, their services must be fully integrated into the design organization and procedure.

To perform this function satisfactorily, we must increase our knowledge of and secure or develop much better information on the economic aspects of physical plant investment in agriculture. Seferovich (2), in his keynote address at the 1958 ASAE-sponsored materials handling conference said this: "When we view the farmer as a manager of capital, we focus attention on the amount and the proportion of capital invested in the various parts of his business and the relative return on each part. This area of farm management is a statistical desert." The establishment of a large-scale, completely mechanized system presupposes a larger total capital investment and a still larger proportionate investment in physical plant. How do you make an intelligent selection of just which of several buildings or equipment items offered or available will result in least cost when all factors, such as function, initial cost, interest, taxes, maintenance, service life, depreciation, obsolescence, environmental response, labor reduction, availability of service, fire hazard, wind hazard, and final salvage or resale, are considered? Should plant cost accounting be on the basis of "annual cost of ownership," unit cost of production, or should the selection be weighted in some manner to favor low intial cost and free operating capital in the early years of the operation of the enterprise? Will complete automation actually reduce labor time and improve the function of the assembly, or will a man only stand and watch it operate while he could be performing some of the automated functions with less complex and costly equipment? What are the size versus unit production cost relationships, and where should a large operation be divided into two or more smaller units? What is the true economic value of housing fattening cattle?

These are only a few of the economic problems related to physical plant investment for which we must eventually find

*Numbers in parentheses refer to the appended references.

answers, but on which we must currently exercise an intelligent judgment in the absence of such definite answers. The research engineer can say that he doesn't know — and inaugurate research to find out. The development engineer can take a little time to find an acceptable solution. The design engineer must commit himself now.

In summary, this presentation is an attempt to break down the over-all design function into the various steps which comprise that function to facilitate its study, to inventory our present engineering and organizational status in the performance of each step, and to concentrate attention on the weakness in our present performance of the initial steps of the design involving the basic economic and engineering decisions most vital to the success of the enterprise as a whole. No suggestions have been offered on the "quick and easy" design of beef production systems; too much of this has been done already. It would be unfair to conclude without stating that some few individuals and organizations have attempted, and with some degree of success, to provide service in the generally weak areas, and their efforts are commended.

Frank, individual appraisals of the problem by the engineering, manufacturing, and distributing agencies involved are needed, but the problem is an industry-wide problem. Acting through professional and trade organizations, the requirements for the organization and operation of adequate design services might be defined, and standard policies adopted for such items as distribution of comprehensive design costs to be assessed against various suppliers of components when engineering charges are treated as an indirect cost. Your serious consideration of such an industry approach to the problem is solicited.

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Livestock-Production Plant of the Future

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At this conference on the confinement system of livestock production, it seems appropriate that some projections be made of the physical facilities and layout required for various livestock enterprises. This is a bit hazardous because much sentiment is associated with the farmsteads which dot the countryside, each with its familiar red barn, the old dwelling and usual cluster of buildings protected by a grove of trees. To suggest that the old barn is a bottleneck to efficient production and therefore should be replaced with structures and equipment which take on the appearance of a factory, is considered by some to border on the radical. But the "old" must give way to the "new." New technologies, specialization brought about by vertical integration, the cost-price squeeze and other forces, are resulting in industrialization of the farmstead. This revolutionary change represents progress. It is summed up ably by Kock and others (1)* discussing the application of automatic control to agricultural operations, ". . . the forces which the family-farm type of agriculture brought into being have obsoleted the family farm with its diversification."

To develop and project new ideas on livestock production systems involving the layout of the physical facilities is difficult. Many new ideas are already in use. Many others are continually being suggested and developed. Each new development or technique offers new possibilities and, therefore, additional ideas. But what is equally or more important is some basis for evaluating existing ideas as well as any new ideas, in order to find practical ones. Since livestock production is basically a process of converting plant energy into such products as meat, eggs, and milk, the efficiencies of these conversions in relation to the inputs of feed, labor, materials, and equipment provide some basis for evaluating a system of production.

Therefore, this paper will discuss, first, the relative efficiency in converting crops into livestock products; second, important trends and developments affecting livestock production systems, and, finally some projections in livestock-production systems involving layouts, buildings, mechanization, and automation.

For this purpose, some distinction will be made between a farmstead in the usual sense and a livestock-production plant highly specialized in its operations. One important distinction is the diversified operations usually carried out on the farmstead, namely, the processing and storing of crops grown on the farm, as well as one or more livestock enterprises. In contrast, a livestock-production plant is for a specialized operation confined not only to one kind of stock, but also limited to some phase of production such as rearing or fattening. It may or may not be located on the farm where the feed is produced. In any case, this discussion is confined to the more highly specialized operations regardless of location.

Efficiency of Feed Conversion

Much has been said at this conference about the functional and basic requirements for satisfactory housing and production, and the combination of components for economical operation. But little mention is made about efficient utilization of energy and materials, especially the ability of principal types of livestock to convert feed into animal products. Due consideration also needs to be given to the "production" systems in relation to the fixed inputs of buildings and equipment as well as feed, power and labor.

The efficiency of the principal types of livestock in converting feed to livestock products is presented in Table 1, on both a weight and an energy basis. While the former is in common use and satisfactory for comparing the yield or output within the same class of livestock, it is somewhat inadequate for comparing one type with another. It is suggested that this may best be put on an energy basis, as indicated in the third, fifth, and seventh columns of Table 1, which show the relative efficiency of the principal types of livestock. (The sources for this information are indicated in the footnotes of the table.) The gross energy values in column 5 are presented in greater detail in

TABLE 1. RELATIVE EFFICIENCY OF LIVESTOCK IN CONVERTING FEED TO LIVESTOCK PRODUCTS

	Feed Intake*		Production		Ratio§	
Livestock	Weight Pounds	Digestible energy† Therms‡	Live Weight* Pounds	Gross Energy Therms	Weight Percent	Energy Percent
Fattening 2-yr	27.0	33.0	3.0	2.21	11	6.7
Beef (1,000 lb)	(Daily)					
Growing and	8.0	12.0	1.9	1.70	24	14.2
finishing pig (200 lb)	(Daily)					
Broiler	8.0	12.0	3.0	2.14	38	17.8
(3 lb)	(Total)					
Laying hen	108.0	170.0	45.0	21.9	42	12.9
(5 lb)	(Yearly)		(300 eggs)			
Dairy cow	47.0	53.5	50.0	15.7	106	29.5
(1400 lb)	(Daily)		(4 percent milk)			

*Data for feed intake and the expected production taken from the National Research Council publications on nutrient requirements for domestic animals (4). (See appended list of references.)

†Published data on digestible energy of livestock feeds. [Gross energy would be more appropriate, but data on the former is more readily available (4).]

‡One therm=1000 kg-cal.

§Ratio of production to feed intake.

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*Numbers in parentheses refer to the appended references.

TABLE 2. GROSS ENERGY VALUES* OF PRINCIPAL FOODS

Product	Dry matter, percent	Gross energy	
		Moisture free, therms per pound	At percent dry matter indicated therms per pound
Beef	25	2.95	.737
Pork	25	3.55	.886
Poultry	25	2.86	.795
Fish		2.86	
Eggs	15	3.22	.483
Butter		4.00	
Milk (4 percent fat)	12.8	2.46	.315
Cereal foods	90	2.04	1.84
Vegetables		1.90	
Fruit		1.99	

*Adapted from Table 5, U. S. Department of Agriculture, Handbook No. 74. "Energy Value of Foods." March, 1955. (3)

TABLE 3. PRODUCTIVITY OF PRINCIPAL LIVESTOCK

Product	Product weight per		Product energy per	
	100 lb of feed, lb	Man-hour of labor, lb*	100 lb of feed, therms	Man-hour of labor, therms
Beef cattle	11.1	29.4	8.2	21.7
Swine	23.8	35.7	21.1	32.0
Broilers	37.5	62.5	29.8	44.5
Laying hens	41.6	36.0	20.1	48.8
Dairy cows	106.0	52.6	33.4	16.5

*Data for 1955-1958, by R. W. Hecht, farm economics research division, U. S. Department of Agriculture.

Table 2. These data clearly show that the beef animal is the least efficient in converting feeds into meat, being only 6.7 percent, while the dairy cow is 29.5 percent efficient in converting feed into milk. This is much higher than broilers which have an efficiency of 17.8 percent.

Table 3 shows the productivity of livestock per unit of both feed and labor input. On a weight basis, broilers have the greatest productivity of the meat animals — 37.5 lb per 100 lb of feed and 62.5 lb per man-hour of labor. This is also true on an energy basis, being 29.8 therms per 100 lb of feed and 44.5 therms per man-hour of labor. The beef animal ranks lowest in productivity, with swine intermediate between beef and broilers.

The productivity of laying hens and dairy cows on an energy basis, in relation to meat animals, is revealing. As shown in Table 1, the dairy cow ranks highest in energy conversion, 33.4 therms per 100 lb of feed. It is substantially higher than that of broilers, the highest of the meat animals. However, the energy of the dairy cow per man-hour of labor is the lowest, being 16.5 therms. This, of course, is in agreement with the well-known fact of the high labor input in dairying.

These energy data may not seem to have much significance, especially at a time when foods of all kinds are plentiful or in surplus. But should we be confronted with an emergency in the future, and given the responsibility for selecting a livestock enterprise which would give the greatest "yield of energy" for a given feed input, data similar to that in Tables 1 and 3 would provide a rational basis for a choice. To illustrate, Garst (5) has proposed that the smaller and underfed Asian countries be taught how to produce broilers and eggs and the required grain be shipped from surplus stock in this country. Poultry is a good choice because of high efficiency in converting feed to meat and eggs, as shown by the above-mentioned data. In addition, such information as this begins to give a much better indication of the maximum efficiencies of conversion possible, when energy of metabolism and digestion and that of the manure are taken into account. Moreover, this kind of data should be helpful in developing a more suitable basis for evaluating livestock-production systems.

Trends and Developments

In considering the future of livestock-production systems, a brief enumeration of important trends and developments which will bring about further changes is in order.

Confinement housing, the subject of this conference, is perhaps the most important trend, especially in the larger operations. It offers a better opportunity for mechanization and automation, and more effective control of both feeding and environment for the animals. Moreover, it eliminates seasonality and makes better use of resources, such as land otherwise used for pasture.

Mechanization is not complete without *automation.* The relatively new science of "cybernetics," highly developed in our space age, will find wide applications in livestock-production systems. Most of the present mechanized operations are of the "open-loop" rather than of the "closed-loop" type in which the feed-back principle is employed for automatic control of the operation.

The trend toward *specialization* in livestock production is rapidly following the pattern established in industry. The production of livestock under contract has speeded up the adoption of new technologies, particularly those which improve production efficiency. More specialization is inevitable.

The productivity of livestock is being increased continually through new technological developments in breeding and nutrition by animal scientists. For example, hens to lay two eggs per day, the beef-type steer to meet the demand for tender beef, and greater efficiency in converting feed to livestock products are in the offing.

Much progress is being made in the control of disease. To be sure, still greater advancements will be made to reduce the probability of any serious outbreaks to wipe out any herd or flock, a criticism often aimed at the confinement system. This means that systems of livestock production can be planned and projected to insure a given yield.

Much has been published on the trend toward *fewer but larger farms.* The present 3.1 million farms will be reduced to 2 million by 1975, according to a recent USDA estimate. Almost half of the farm purchases in 1959 were for farm enlargement.

An appreciation of the value of a *systems concept* has been developed among those concerned with production. Designing plants for producing livestock is like developing an industrial plant. It must be designed for a capacity, efficiency, and for a market.

Livestock Production Systems and Plants

The patterns of future livestock-production plants will reflect highly specialized operations, regardless of whether they are located on or off the farmstead. In general, the size of the physical plant for each principal livestock enterprise will fall into two categories: small or large. The former will be essentially a one-man unit and the latter either multiples of one-man units or one large unit in which several men perform separate functions under one manager. The latter will be either a very large commercial or custom-type operation.

The size of the smallest operations is determined by the number of animals one man can handle. With all the routine operations fully automated, the ability of the one man to manage and supervise becomes the limiting factor. Surely this point has not as yet been reached at the present level of development. The degree of automation determines to a large extent the maximum size of the smaller operations.

The layout, nature and arrangement of the physical plant in a highly specialized livestock operation will probably not change too much, even with the adoption of some new practices and techniques. Automation, improved methods of handling manure, and new developments in structures may result in some changes in the outward appearance of the physical layout. However, these changes will be primarily in the interior arrangements and in the operations. At any rate, whatever the changes in the system, buildings and equipment, or size of operations, rapid advances will be made to increase productivity. Automating many of the operations including record keeping, so essential for effective management, deserves a high priority. The handling of manure

presents a variety of problems with different livestock and in different areas, for which satisfactory solutions must be found. Slatted floors, if found to be satisfactory for large animals, is a likely possibility. It eliminates the problem of bedding as well as offering a solution for disposition of the manure. In dairying, a substantial reduction in labor can be effected if the milking as well as handling the manure can be automated. The possibilities of some of these in principal livestock-production systems will be discussed.

Milk Production

The greatest need for reducing labor is in dairying, since the dairy cow is the most efficient converter of plant energy into food energy. The routine work of milking, cleaning, bedding, and manure handling is a stigma of this enterprise. Would it not be wonderful if these operations could be automated? Also, would not the same be true if the feed consumed by each individual cow and the daily records of milk could be obtained automatically? Some good "space engineering" can bring this about. It is high time that the dairy cow be given an assist because she is surely doing her share.

Automatic milking may be difficult to accomplish, but the expenditures for labor in milking alone would justify a substantial capital investment in equipment. For example, with present mechanical-milking methods the yearly labor cost for milking 200 cows at 6 cents per milking is between eight and nine thousand dollars. Assuming that all labor in milking could be replaced by an automatic milking machine, an investment on the order of two to three times the annual labor cost would seem justifiable. The major problem is placement of the claw on the udder. Its removal is much easier since a device has already been developed to indicate when milking is completed (6). In this development, the operations of placing the milking claw on the udder will likely be semiautomatic at first, being done by hand or possibly by remote control.

Equipment has already been developed which meters automatically the concentrate rations to each individual cow in proportion to her production, as she is being milked, as well as indicating the amount of milk (6). Combined with this device is an indicator which shows when milking is completed. These operations need to be integrated with a computer to record and summarize the information in a form suitable for management purposes. This would facilitate the detection of any abnormal conditions in a cow at the time of milking.

The slatted-floor system, being tried in the Scandinavian countries and also in England for cattle and hogs, may have some possibilities in handling the urine and dung from dairy cows. If this should prove satisfactory for dairy cows, the problem of bedding including its storage, spreading, and handling would be solved. The manure drops into a pit below to be stored or removed by flushing or by mechanical means. Liquid methods of handling have promise, providing that the manure is free from stems and long fibers which come from feeding such roughages as hay. Pelleted feeds including those which contain roughage would avoid this difficulty. The entire feeding and resting area under roof would preferably be slatted and therefore require little attention, except for occasional application of sawdust and cleaning with a hose. The slatted floor area per cow might be substantially less than that recommended presently for resting area.

A futuristic milk-production system for lactating dairy animals, identified as the "pentairy," has been proposed by R. B. Furry, extension agricultural engineer, Cornell University (2). It consists of five dome-shaped housing and feeding units, 100 ft in diameter and holding 100 cows each. These are spaced about a milk plant. A covered two-way alley connects each unit with the milk plant, in which the milking unit is mounted on a rotating platform for continuous milking. (For more details, the descriptive literature prepared by Furry should be consulted.)

The problems of manure disposal vary with locality. In any case, some provision must usually be made for storing periodic accumulations after removal from the yard or resting area. Furry (2) proposes that drying with solar heat supplement liquid-manure handling at opportune times and further that the evaporated moisture be conserved and stored for reuse in cleaning and for manure removal.

It would seem that the heat pump would be admirably suited for accomplishing the two-fold job of evaporating and condensing the moisture in the drying process. Preferably the process should be continuous, the admixture of urine and dung being dried and stored as it comes from the housing area.

Beef Production

Kock (1) has proposed a method for automatic branding of cattle for permanent identification of each animal with colored permanent ink for either visual or automatic reading at any later time. He proposes this for breeding line control and for permanent records.

A type of branding which will permit automatic identification by a recorder makes it possible to record automatically the weight of growing and fattening beef animals to observe their rates of gains. The animals can be made to pass through a suitable chute or passageway in the course of moving between resting and feeding areas, which may be several times daily. Each time an animal passes through the chute, he can be weighed, providing the equipment is in operation. The weight is recorded by means of load cells supporting a platform flush with the floor of the chute. The data are recorded and summarized at a remote point as in an office removed some distance from the weighing station. This information is invaluable to the cattleman in managing his operations effectively. Even the culling and sorting of cattle can be automated. For example, animals above or below a selected rate of gain can be sorted automatically, if one or more gates suitably arranged are controlled by the recorder.

Egg Production

The production of eggs as well as broilers has been highly developed and mechanized. However, much progress is yet to be made, especially in the area of automation. The production plant will probably not be too far different from that at present. The environment for laying hens will be automatically controlled, made possible by buildings which are insulated and equipped with modern air conditioning and lighting. The buildings will be larger and higher with sufficient unobstructed head room to permit three and four tiers of community wire cages holding 10 to 20 hens each. The size of the building will be determined largely by the number of laying hens one man can handle, which may be 20,000 or more. With automatic and mechanized feeding, watering, egg gathering, and manure removal, only sufficient space between rows of cages is provided to care for hens and to service equipment. A tier of single or double row of cages may be mobile for either lateral or parallel movement, or both, for either inspection or servicing, and to utilize space ordinarily used for aisles and alleys. The population density of hens in such a house would produce enough excess heat to require cooling rather than heating in the coldest weather, even in a building with moderate insulation.

All principal operations are being mechanized in egg production. Some of the important processing operations, such as egg candling, have not as yet been solved but the breakthrough is sure to come. The possibility of removing eggs from their shells, repackaging them, and reclaiming the shells, is intriguing and worthy of attention. The candling may be easier in the case of eggs without shells, indicating the possibility of combining the two processes.

The continual mechanical removal of manure from each tier in each row of cages will help to eliminate ammonia and other odors. Moreover, a continuous system of dehydration at the point of collection may be feasible. This can be coordinated with the handling of dried manure in bags or in bulk for sale or other disposition.

As already mentioned, the application of computer methods to keeping records of eggs would greatly assist in effective management of egg production. Automatic marking of eggs similar to that suggested for automatic branding of livestock (1) would make it possible to identify the egg with the cage from which it came. This would enhance the record keeping and permit quick detection of a falling off in production of any one cage.

Summary

The farmstead will experience some drastic changes in the future due to the rapid specialization in livestock production. It will take on the appearance of a plant or factory arranged and designed to produce efficiently one type of livestock or one kind of livestock product. The plant may not even be a part of or located on a farm. The operation of the plant will be self-contained and may be quite independent of the production or even the processing of feeds for the livestock. *(Continued on page 654)*

Costs and Benefits of Engineered Farmsteads

V. W. Davis and R. N. Van Arsdall

THE speakers at this conference have been asked to consider in detail the contribution to production of a farmstead. The design of a beam to support a grain bin or the size of a motor to power a feed mill are essential kinds of information. However, if costs and benefits are to be measured in monetary terms rather than on a purely subjective basis, it is also necessary to know why the grain bin is needed or what the mill can be expected to contribute to production. Once the physical relationships are known — the specific effects of controlled environment on feed efficiency — then managers can use economic criteria to guide their decisions. Perhaps, therefore, the examples that we have used for illustrative purposes will help to establish an analytical pattern in which new input-output relationships can be appraised as they become known.

Many studies and analyses have been made of the separate components of farmsteads. Questions concerning investment, annual costs, labor requirements, and the like can be answered with little difficulty. Information about the benefits derived from these inputs is considerably more elusive. The problem is further magnified when measures of costs and returns are needed for the composite of inputs that make up a farmstead. Studies of complete farmstead systems including both the end result and the interaction of all parts are practically nonexistent. This area represents the "outer space" of our investigations of farm buildings and farmstead equipment.

What Is an Engineered Farmstead?

A farmstead is described in the *Encyclopaedia Britannica* as a group of buildings and their adjoining yards, roads and gardens. Libraries contain many books that describe the components of a farmstead from frostline to snow load. But no publication yet written so simply and tersely describes the importance of a farmstead as does Webster when he says it is "a farm."

What Webster's definition lacks in detail, it makes up in meaning. A farmstead functioning as a system of many components determines to a large extent the effectiveness with which other resources can be utilized in livestock production, the productive capacity of the farm organization per man, and often whether an enterprise or farm business can even exist.

A farmstead provides many things to the farm family and the farm business, but its chief function, and the one with which we must largely concern ourselves, is to produce farm income. Improved organization of the farmstead can contribute to higher income by decreasing costs per unit of production; by protecting, changing, or increasing quality or quantity of the product; by adding time value to the product; by increasing the productive capacity per worker, and in other equally important ways.

Engineered farmsteads are those which perform their functions effectively and economically through time. They provide for different combinations of labor, equipment, and structures to meet a range of business needs. They provide for a high level of efficiency in the use of labor, equipment, and structures in the handling of materials and performance of essential livestock chores at different levels of mechanization. They provide buildings and equipment designed and combined to perform specialized functions for the enterprises which they serve. But they also embody flexibility both in the components and in the system as a whole to permit changes in size or type of enterprise, and to make room for technological changes in methods of production. Components of an engineered farmstead are integrated so that they function as a system of matching parts. The system is planned as an integral part of the whole farm business. It is consistent with the capital position and long-term objectives of the farm operator. It is engineered in the very broadest meaning of the term from mechanics through economic considerations and includes esthetic values of the farm family.

Farmstead — A Factor of Production

It must first be recognized that a farmstead and its components are factors of production the same as are feed used in dairying and the fertilizer applied in crop production. A farmstead, however, makes its contribution to production in less direct and less discernible ways than do some other factors with which we readily associate input-output ratios, such as pounds of feed per pound of pork. Also, the return for investment in buildings is expected to come gradually over a period of many years, while an outlay for feed may be returned in the same week that it is made.

We need to know the nutritional needs of livestock — not just the needs for maximum production, but a wide range of responses from different rates and different kinds of feeds. This is a problem of measuring inputs and outputs, but equipped with such information, we can price the feed and the meat, milk, or eggs and make calculated decisions on a feeding program.

We need exactly the same kind of information for the farmstead input. What needs do the various enterprises have that a farmstead can provide? What response can be expected from different types of facilities? A farmstead is not an all-or-nothing proposition. Facilities can be provided in differing degree, just as in a feeding program. If the responses can be measured in the same sense as feed required per hundredweight of milk, then decisions about farmsteads can be made on a more precise basis than is now possible.

As the lack of data suggests, measurement of the contribution of the farmstead input is difficult, yet the magnitude and permanence of decisions that must be made with regard to farmsteads emphasize the importance of this problem. Consider the reaction of a dairyman if he were told that he must decide at one time the composition and quantity of the feed ration that he intended to use for the next 20 to 30 years in his dairy operation.

COSTS OF ENGINEERED FARMSTEADS

Direct Costs of Farm Buildings

Investments. Farm buildings account for a substantial part of the capital invested in agriculture. In 1959, they constituted 23 percent of the total value of farm real estate in the United States. Depreciated value of buildings ranged from more than half the value of farm real estate on the intensive livestock farms in the northeastern states to about 15 percent in the western half of the country. Livestock and materials-handling equipment involve a substantial but smaller amount of capital. Dual use of tractor power for field work and livestock operations makes it difficult to estimate what farmers have spent for this purpose.

Buildings and equipment account for 15 to 25 percent of the capital needs of beef-raising and beef-feeding operations. These two inputs take nearly half the capital input in hog, sheep, and dairy enterprises and nearly three-fourths of the total in poultry enterprises. Their proportion of total investment is a few percentage points greater in highly mechanized systems than in those relying largely on manual methods. (See Table 3 for midwest conditions.)

Investments in livestock buildings and equipment are more imposing when expressed in terms of capital needed to establish a fully mechanized system large enough to serve the livestock that can be handled by one man-equivalent. Figures range from around \$20,000 for beef-raising operations to more than \$50,000 for hog-raising, poultry, and beef-finishing operations.

Still more significant is the building-equipment category of investment requirements. First, this investment bundle repre-

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sents intermediate and long-term commitments, largely the latter. Results of errors in analysis or judgment may persist for 40 years or even longer. Operating capital, even though it may represent a high proportion of the total as in beef raising, can be manipulated on a yearly basis. Second, capital needs other than for buildings and equipment are usually substantial. An operator considering a $50,000 outlay for a completely mechanized farmstead may have to come up with as much as a quarter of a million dollars, exclusive of that for land, to operate to capacity an enterprise such as beef feeding (Tables 3 and 4).

Annual Costs. The annual costs of owning and using farm service buildings include allowances or cash payments for interest on investment, depreciation, taxes, insurance, maintenance, and repairs. These costs reflect a major investment, but they do not represent a substantial part of the cost of producing any of the chief farm products.

Expenses for buildings are commonly expressed as percentages of initial investment. Normally they total 7 to 13 percent of initial investment (2 to 5 percent for depreciation, 5 to 6 percent for interest on average value, 1 to 3 percent of the first cost for maintenance and repairs, 1 to 1.5 percent of full value for taxes, and 0.5 percent of full value for insurance). Producers who fear a high rate of obsolescence or who have very profitable alternative uses for limited capital may set these costs so as to total higher than the maximum indicated above. The cost of owning and operating livestock and materials-handling equipment includes the same categories of costs as do buildings with the addition of power charges. Annual overhead costs usually amount to about 15 percent of initial cost.

Farm service buildings and structural equipment are among the most adaptable of all agricultural inputs with respect to recovery of cost. Only taxes, formal insurance, some repairs, and interest on borrowed funds require cash outlays once buildings have been constructed. These expenses are a small part of total annual cost. Farmers can thus carry through lean years with little outlay for buildings, replenishing depleted reserves during prosperous periods. This leeway in the use of capital resources adds flexibility to the cost structure. But it sometimes leads producers into a false sense of security that is rudely shaken when replacement needs bring the realization of the long-run building costs that must be borne. Farm or enterprise planning must include all costs, whether cash outlays or allowances for depletion and foregone opportunity.

Based on new cost of all facilities, and including the cost of all buildings, lots, fences, and structural equipment, the building input for livestock enterprises on midwestern farms ranges from about 3 percent of the total cost of production for small grains to 10 percent for dairy enterprises. Estimates of the importance of buildings in the cost of producing some other main products fall between these extremes.

Illinois farm cost-account data show buildings as having a smaller share of the cost of producing livestock. Averages from Illinois farms on which detailed cost-account

Enterprise	Percent of production cost for buildings
Dairy	10
Poultry	9
Beef cattle	8
Sheep	7
Hogs	6
Corn	5
Small grain	3

records were kept between 1953 and 1958 generally place the building input below 5 percent of total cost*. This is partly because some farmers had old buildings that had been revalued one or more times, partly because the building input was inadequate on some farms, and partly because grain storage was not charged against livestock in the cost analyses. Generally these records showed power, machinery, and equipment to be a more costly input than buildings. The opposite is true when the power, machinery, and equipment input is compared with the estimated building input based on new cost. As mechanical equipment continues to be substituted for manpower, the relative importance of the equipment input will increase.

Enterprise	Percentage of production cost for: Power, machinery, and equipment	Buildings
Hogs	6.3	2.1
Feeder cattle	4.4	2.8
Dairy	6.0	4.2
Beef herds	4.0	2.6
Laying flocks	6.5	5.2
Sheep	0.9	6.3

Flexibility in Farmstead Planning

Most farm enterprises, especially livestock enterprises, require investment in durable buildings and equipment. This investment, once made, is fixed through counterpart annual charges in the cost of production of that enterprise. The producer no longer has the opportunity, except through salvage disinvestment, to consider alternatives for the investment of those funds. Alternatives in the use of the investment can be available only if flexibility has been built into the original investment.

Such flexibility refers to the variations in production that can be managed within the boundaries of a fixed investment. It makes it possible to increase production or to shift enterprises in case of changes in cost-price relationships. Further flexibility may be achieved by minimizing fixed investment, thus giving producers more latitude to move out of production in case of price declines. High overhead costs in relation to variable costs may force a farmer to produce because his best solution is to maintain production so long as he covers variable costs and gets something toward fixed costs.

Long-Term Capital Investments and Opportunity Cost

Durability and flexibility of farm structures are often closely associated, ordinarily in inverse relationship. To illustrate this relationship between the term of an investment, or the accounting-period life of that investment, and the cost of the investment to the producer, let it be assumed that a dairy farmer plans to build facilities for a 30-cow dairy herd. Let it be further assumed that he has reduced his choice to either a $12,000 stall barn with an anticipated life of 40 years, or a $9,750 pole-frame, loose-housing barn with a milking parlor having an expected 20-year life. The two setups will serve equally well in the dairy enterprise. Which one should this dairyman construct?

The stall barn involves a first cost of $12,000 and creates an annual depreciation charge of $300 on the basis of the straight-line calculation method. To provide the same 40 years of service with loose housing, it would be necessary to construct a second $9,750 loose-housing layout at the end of the first 20 years. This would involve a total investment of $19,500. The annual charge for depreciation computed on the same basis as for the stall barn would be $488. Other costs, exclusive of time, are assumed to be the same for both systems.

Neither investment nor depreciation, however, give enough information to answer the question as to which layout to build. The "real" cost of investing capital in buildings or other farmstead improvements is the return that could be obtained from these same funds invested in the most profitable alternative.

Now let it be assumed that the dairyman in this example has ample capital and that 5 percent is the highest return he can expect on any other farm or non-farm investment. Five percent, then, is the opportunity rate of return at which the building investments must be discounted to determine their original capital cost.

The question is whether to pay out $12,000 for a stall barn now, or $9,750 for a loose-housing system now plus another $9,750 in 20 years. If the loose-housing system is selected, the dairyman will have $2,250 to invest elsewhere that would not be available were he to construct the stall barn. The total cost of the loose-housing system is $9,750 now plus the amount that must be invested at 5 percent interest to build a fund sufficient to replace the $9,750 barn in 20 years. Compounded annually this amount is equal to $\$9{,}750/(1+0.50)^{20}$ or $3,679. The total 40-year cost of the two loose-housing systems is, therefore, $13,429 ($9,750+$3,679). This is greater than the $12,000 cost of the stall barn. The $2,250 difference between original cost of the two systems is not sufficient to build a replacement fund at a 5-percent rate of return. If the dairyman cannot better this rate of return, then he should build the stall barn.

Further appraisal of the situation may suggest that it would be wise for this farmer to invest in the shorter life loose-housing system, even though it would apparently be more expensive than the stall barn. Probable changes in production techniques and other uncertainties put a premium on the flexibility which is characteristic of loose housing. Permanence and in-

*See annual detailed cost reports for selected areas in Illinois published by the department of agricultural economics, University of Illinois, Urbana. (Data for sheep were taken from an unpublished study of Illinois farm flocks.)

flexibility of farm buildings have long been one of the chief stumbling blocks to rapid adoption of up-to-date methods and equipment in livestock production.

Had capital been limited on this farm to the extent that alternative investment opportunities would yield 10 percent, loose housing definitely would have been the indicated choice. Using 10 percent as the rate at which the barn costs should be discounted, the loose-housing system would require an immediate investment of \$9,750, plus an additional \$1,451 invested at 10 percent compounded over 20 years to pay for the second layout: $\$9,750/(1+0.10)^{20} = \$1,451$. The resulting \$11,201 is less than the cost of the stall barn. The more limited the funds, the higher the alternative rate of return and the longer the investment period, the more important are the considerations illustrated in this section†.

BENEFITS OF ENGINEERED FARMSTEADS

The cost side of the farmstead equation has been dealt with rather thoroughly by farm planners. For the most part, however, they have given less attention to measurement of the output side.

A common approach to the problem of determining allowable building investments has been to capitalize the portion of gross income available to pay the annual costs of buildings. Over a period of years, average building costs have ranged from 6 percent of cost of production for hog enterprises to 10 percent for dairy enterprises. Assuming that factors of production are to be rewarded in proportion to their share of total costs of production, this part of gross income is allotted to cover annual building costs. This annual allowance then can be converted into investment terms.

As an example, assume a 30-cow dairy herd producing an average of 10,000 lb of milk annually, with a value of \$4.00 per hundredweight for milk plus \$30 for the value of a calf. Gross income equals \$12,900. Past records have shown that buildings costs are 10 percent of the total cost of operating a dairy, so it is assumed that 10 percent of gross income, or \$1,290, is available to pay annual building costs. Capitalized at 9 percent, which is the average percent of initial investment to cover annual building costs, \$1,290 is converted into an allowable initial outlay for dairy buildings and structural equipment of \$14,300.

By thus using past expenditures of other farmers as a guide to type of facilities and total outlay for buildings, a farmer can guard against excessive investment. But in following this criteria he also foregoes the opportunity to develop a farmstead system that is much better than the average.

A more positive approach is much to be desired. If the net effect on production of specified types of facilities can be measured, the question often asked, "How much rent can my livestock afford to pay?" can be answered in meaningful terms. Much work has been done on this facet of the farmstead problem. Some of the answers that are already known are illustrated in the remaining portion of the paper.

Meeting Legal Requirements

Type of buildings and equipment may be involved in meeting the legal requirements for production or storage of farm products. Production of milk for certain purposes and the storage of crops to be delivered to the U. S. Government under provisions of the commodity stabilization program provide two examples of this phase of farmstead engineering.

Milk production‡. Public health agencies have established minimum requirements for dairy buildings and equipment for use in production of milk to be marketed for fluid consumption. Meeting these requirements ordinarily requires an investment in addition to the investment for basic needs of a dairy herd. Whether this extra investment will be profitable depends upon the premium paid for milk to be used for fluid consumption and the amount of investment. Unlike many of the input-output relationships of buildings and equipment, however, the profitability of these alternatives can be calculated easily and with considerable accuracy.

The gain from making an investment necessary to meet minimum legal standards can be calculated precisely if price differentials are known. For example, a 30-cow herd averaging 10,000 lb of milk per cow would yield \$300 additional gross income for each 10-cent increase in the price of milk. A price differential of \$1.00 between ungraded and grade A milk would result in \$3,000 more gross income per year. Net gain would be \$3,000 minus the annual cost of improvements above basic investment to meet minimum legal requirements. The actual cost of improvements can be determined accurately by first obtaining from inspectors of the health agency an itemized list of minimum requirements. These necessary improvements can then be priced by an appropriate dealer or contractor.

But let it be assumed for purposes of this example that the minimum extra outlay for equipping this 30-cow dairy operation to produce grade A milk for fluid consumption rather than milk for manufacturing purposes is \$5,000 at an annual charge of 9 percent. Then \$2,550 would be the net gain from the extra investment.

Looking at the problem another way, a farmer may wish a guide to the maximum allowable or breakeven investment point. At a capitalization rate of 9 percent, each 10-cent increase in price of milk would permit additional investments up to \$3,330. If the added returns were capitalized at 25 percent, enabling the farmer to pay off in approximately five years rather than twenty as with a 9-percent rate, the breakeven investment would be \$1,200 for each 10-cent increase in price differential, or \$12,000 if the increase were \$1.00 per hundredweight of milk.

A farmer must study many other factors before deciding what class of milk to produce. But other things being equal, the cost and benefits of meeting legal requirements can be measured with considerable accuracy. Many farmers who are now producing unclassified milk might well profit from such an evaluation of their dairy business.

Corn storage. Corn provides an excellent example of legal requirements to be met in the storage of farm products. Farmers have always been confronted with the decision of whether to store market corn for later sale or to sell at harvest time.

During the past few years, many farmers have had the additional alternatives of either disposing of some of their corn under the provisions of the Commodity Stabilization Program by entering into a purchase agreement or applying for a loan with the Commodity Credit Corporation. The benefit of this program to the farmer lies in the elimination of the risk of fluctuating seasonal price. If the market price rises above the support price, he has the option of selling his corn and paying off the government loan or cancelling his purchase agreement. Should the market price remain below the support price, he is assured the guaranteed support price when the corn is delivered to or taken over by the CCC.

To derive the benefits of the price support program, the farmer must meet certain legal requirements in regard to storage structures and conditioning equipment. These requirements are expressed as minimum standards or specifications. If the minimum specifications are not met, applications for loans are not accepted, and the producer must handle his corn through regular market channels. Until recent years, compliance with acreage quota was also involved in minimum specifications for loans.

Corn, for example, must be stored in a structure at a moisture content such that the quality will be maintained or improved during storage. Until the corn is taken over physically by the CCC, it is the farmer's responsibility to maintain the quality and protect the corn.

The support price of corn averaged \$1.51 per bushel during the 10-year period 1949-58 compared with an average annual market price received by farmers of \$1.37 per buhsel§. The support price was lower than the market price only two years out of ten—1950 and 1951 during the Korean War. The gross returns from storage, however, have been greater than the 14-cent differential indicates. First, during 1950 and 1951 farmers had the option of selling their corn at an average of 5 cents per bushel higher than support price. Second, the seasonal index of corn prices received by Illinois farmers, 1949-58, ranged from about 94 in October and November to approximately 104 in July, August, and September||. Comparison

†For further discussion of this topic, see Heady, E. O. and Jansen, H. R., *Farm Management Economics*, Prentice-Hall, Inc., New York, 1954, Ch. 14.

‡For a more detailed discussion, see Bartlett, R. W., and Whitted, S. F., "An Economic Analysis of Federal Regulation of the St. Louis Milk Marketing Area," University of Missouri, September 3, 1958.

§Agricultural Statistics, 1959, USDA, Table 51.

||Walker, Francis E. "Seasonal Indexes of Illinois Farm Products" Department of Agricultural Economics, AE 3411, 1959.

of harvest price with support price spreads the average price differential by an additional 8 cents per bushel. Thus farmers had a 22-cent price spread during 1949-58 to cover the cost of corn storage structures and the related costs of storage including shrinkage, rodent and handling losses, treating and conditioning, and interest, taxes, and insurance on the value of the corn during storage.

Annual costs of corn storage structures usually range from 4 to 8 cents per bushel of capacity, and the related expenses for shrinkage, rodent damage and the like account for a similar amount. Thus, provision of farm storage for corn that would meet minimum standards of the CCC could have resulted in a net gain to the farmer as high as 14 cents per bushel during the 1949-58 period. Possibly the gain could have been even greater in the case of farmers who, as in the preceding dairy example, had the basic corn storage facilities but lacked some relatively inexpensive feature necessary to qualify for minimum standards.

Value of Product

The quality and value of farm crops may be affected by type of storage structure. Two such examples are found in the storage of silage where the structure may vary from a stack on the ground to a permanent upright airtight silo, and in the storage of high-moisture ground ear corn in upright airtight or essentially airtight silos versus conventional crib storage. In general, the more we attempt to maintain or improve quality of crops in storage, the greater are the costs to provide such facilities.

The nutrient losses during storage of silage are at a minimum when using a steel glass-lined airtight silo and at a maximum in trench or bunker silos. Estimated total dry matter losses range from 8 percent for the airtight structure to 21 percent for trench silos when silage is stored at 75 percent moisture content#. For a capacity of 200 tons, the structure cost per year ranges from $1.85 per net ton for the upright airtight structure to $0.27 per net ton for a horizontal unlined trench silo**. The higher initial costs of storage structures are in general mostly returned in reduced storage losses. The more permanent facilities will normally provide features other than increased feeding value or reduced nutrient losses. Such considerations as ease of filling and removing the silage and adaptability to mechanized feeding operations may be involved in the final choice of the most economical structure.

A change in method of storing and processing ear corn for cattle feed may increase feeding value. Research reports indicate 10 to 15 percent increase in feeding efficiency for cattle when comparing high-moisture ensiled ground ear corn with low-moisture corn dried in a crib and then ground. Beeson *et al*††, suggest that it is reasonable to expect that beef cattle utilize the cob portion of the high-moisture ensiled ground ear corn better than the cob of regular ground ear corn. To justify the change economically, the high-moisture corn method needs to save only what it costs above the least-cost method of storage. Assuming a choice between ear corn storage in a conventional crib or high-moisture ground ear corn storage in a silo, the additional feeding value of the ensiled high-moisture corn must at least pay for the costs above conventional storage. As with choosing type of structure for silage, other considerations, such as advantages or disadvantages of early harvest and adaptability to mechanical-feeding operations, will be involved in choosing the method and associated storage and feeding facilities.

Simplify or Eliminate the Job

It is not uncommon to find input-output ratios differing as much as 500 percent among similarly equipped enterprises. Differences result from varying work methods and arrangement of facilities rather than level of mechanization. An engineered farmstead provides for most effective use of these facilties. Often labor can be reduced and the work made easier by simple rearrangement of facilities; for example, the location of feed storage for cattle or hogs near the feedlot or in the same building for poultry. Possibly a change in ration, reducing the number of kinds of feed, will simplify the feed processing and distribution chores.

This facet of farmstead engineering may even extend to the fields, where a change in method of harvesting can eliminate jobs, facilities, and equipment in the movement of feed from the field to the feedlot. The many work simplification studies that have been made provide ample evidence of the value of simplifying or eliminating jobs in both livestock and crop production.

Environmental Factors

Farm buildings and equipment have a definite contribution to make in providing optimum environment for livestock production. Producers need facilities that will permit production planning independent of the weather. The trend toward such facilities is particularly evident among swine growers, who are using temperature-controlled central farrowing houses and enclosed finishing buildings for year-round production. Poultry men are also making extensive use of equipment and structures designed to stabilize environment at desired levels.

Numerous research studies have been conducted to determine the effect of environment on the health and production efficiency of livestock and poultry. However, the major problem in evaluating the results of these environmental studies on an economic basis is the lack of a control, standard, or average against which the response can be measured.

In evaluating the benefits as shown by the environmental studies of swine and poultry, described below, it should be recognized that feed conversion ratios were obtained under conditions of constant temperatures and presumably with high levels of management. Benefits are determined in this example by comparing the best feed efficiency obtained in the experiments with average herd or flock production efficiency obtained under farm rather than laboratory conditions. Cyclical temperature variations occur in farm production while animals in research tests are usually subjected to constant temperatures, thus posing a limitation to practical application of the results of these studies.

Swine. A study of optimum growing temperatures for hogs raised under constant-temperature conditions in a controlled-environment chamber shows that the optimum temperature for feeder pigs depends upon size of the animal, but that above-freezing temperatures are desirable in all cases‡‡. Hogs ranging in weight from 80 to 450 lb were exposed to temperatures of 40 to 110 F with a relative humidity of 50 percent and constant air velocity of 25 to 35 fpm.

The temperature at which daily gain was maximum varied from 73.5 F for 100-lb hogs to 61 F for 350-lb hogs. For weights from 100 to 250 lb, maximum gains occurred around 70 F. Heavy hogs made the cheapest and most rapid gains at a temperature of 60 F. Lighter pigs made their best gains at higher temperatures; pigs weighing around 100 lb did best at temperatures of 70 F with a feed efficiency of 255 lb of feed per 100 lb of gain. Feeders weighing around 200 lb made most efficient gains at 60 F with feed requirement of 360 lb per 100 lb of gain.

Using data from these studies as a guide and making certain assumptions as to value of pork, cost of feed, and the like, it is possible to determine the maximum investment that can be made to provide optimum environment:

1 Feed efficiency: Pounds of feed (per 100 lb of gain from 40 to 220 lb of weight)

   (a) Standard: 360 lb of feed

   (b) Optimum: 325 lb of feed (255 lb of feed per 100 lb of gain from 40 to 100 lb and 360 lb of feed from 100 to 220 lb)

2 Savings in feed: 35 lb of feed per 100 lb of gain, or 63 lb of feed per hog fed from 40 to 220 lb weight.

3 Value of savings in feed: $1.42 (63 lb of feed times 2½¢ per pound)

4 Breakeven investment for equipment to control temperature and humidity: $8.14 per hog fattened

$$\left(\frac{\$1.42-(20 \text{ percent operating costs} \times \$1.42)}{14 \text{ percent annual fixed cost of equipment}}\right)$$

5 If three lots of hogs use the same facilities, an annual investment of $24.42 per animal could be justified.

Poultry. USDA research tests at Beltsville, Md., from 1951 to 1954 indicate that the

#Shepherd, J. B., Gordon, C. H., and Campbell, L. F. Developments and problems in making grass silage, USDA, ARS, BDI-Inf-149, May 1953.

**Hendrix, A. T. Equipment and labor requirements of different methods of storing and feeding silage, unnumbered mimeo, Univ. of Georgia, Athens.

††Beeson, W. M., and Perry, T. W. The comparative feeding value of high-moisture corn and low-moisture corn with different feed additives for fattening beef cattle, *Journal of Animal Science*, Vol. 17-2, May 1958.

‡‡Bond, T. E., and Peterson, G. M. Hog houses, USDA, Misc. Publ. No. 744, January 1958, and Heitman, Huber, Jr., Kelly, C. F., and Bond, T. E. Ambient air temperature and weight gain in swine, *Journal of Animal Science*, 17:62-76, 1958.

optimum temperatures for egg production range from 45 to 65 F§§. The results also show that protecting the hens from low temperatures saved feed, while protecting them from high temperatures resulted in higher egg production. A maximum production of 78 eggs per day per 100 hens occurred at 55 F. At 45 and 65 F, respectively, production was 74 and 75 eggs per day per 100 hens. The least feed per pound of eggs produced occurred between 45 and 65 F.

The procedures followed in the pork analysis can also be used to determine the maximum allowable investment for poultry facilities.

1 Egg production
   (a) Standard: 60 percent
   (b) Optimum: 76 eggs per 100 hens per day (range 74 to 78 for temperatures 45 to 65 F)
2 Increase in egg production: 16 percent, or 58 eggs per year
3 Net value of increased egg production: \$1.62 per hen per year (4.8 dozen eggs × 35 cents per dozen minus cost of labor for gathering, packing, and washing eggs and variable equipment costs at 1.2 cents per dozen eggs)
4 Break-even investment for equipment to provide temperature for maximum egg production: \$9.29 per hen

$$\left(\frac{\$1.62-(20 \text{ percent operating costs} \times \$1.62)}{14 \text{ percent annual fixed cost of equipment}}\right)$$

Productive Capacity of Labor

Low production per unit of labor has been one of the key stumbling blocks in the path toward a suitable level of income for farmers engaged in livestock production. Increasing the production per unit of labor requires use of highly productive animals and the means for handling them in volume. Neither approach is successful when used alone. Illinois DHIA records show, for example, that 12 cows producing 14,766 lb of milk annually will return the same total dollars above feed cost as will 63 cows averaging only 5,676 lb of milk. Obviously, the number of cows by itself is no criteria of productivity. Conversely, even the best cows will not yield a satisfactory income if the type and organization of dairy facilities limit worker capacity to only 10 or 12 cows.

Many farmers in the midwest are now handling only one-third to one-fourth the number of livestock per unit of labor that they could manage with efficient work methods, convenient arrangement of buildings, and the mechanical equipment readily available on the market. For example, a 16-cow dairy herd is the equivalent of a full work load for the average midwestern farmer who does most of his chores by hand (Table 1). Records show that addition of standard dairy equipment and use of improved work methods raises the capacity of the average dairyman to 23 cows. This average dairyman, however, is still considerably off the pace as the most efficient dairyman can handle 31 cows with the same labor and equipment. Mechanization plus efficiency is the key to productivity on these farms.

Recent technological advances have doubled the productive potential of dairymen. Full use of the equipment and know-how presently available would make it possible for a good dairyman to handle about 65 cows per man equivalent, excluding production of dairy feed. Some systems staffed by topflight workers have already been organized at the rate of nearly 100 cows per man.

The results of improved work methods, organization of facilities and mechanical equipment are also felt in other enterprises in the midwest (Table 1). Possibilities for increasing the volume of output per man are greatest where materials handling can be centralized and automated, where labor for materials handling has been a substantial burden, and in enterprises which are now least developed in a particular area. This situation for the midwest undoubtedly has its counterpart in other areas of the United States.

Improved work methods increase the productive capacity of farm workers without adding to cost. Mechanization adds to cost when labor is treated as a residual claimant rather than one of the inputs. Increases in unit cost of production, however, are relatively small, as indicated in Table 2. Income over costs decreases by only \$10.50 per dairy cow between systems relying largely on manual labor and those which are fully mechanized. Within the limits of equipment-structure combinations available today, the gains in income will probably much more than offset increases in unit

§§Ota, Hajime. Houses and equipment for laying hens, USDA Misc. Pub. No. 728, November 1956.

TABLE 1. PRODUCTIVE CAPACITY OF ONE-MAN EQUIVALENT UNDER SPECIFIED LEVELS OF EFFICIENCY AND DEGREES OF MECHANIZATION*

		Capacity of one-man equivalent with			
		Low mechanization†	High mechanization†	High mechanization†	
Enterprise	Unit	Poor methods (units)	Average methods (units)	Efficient methods (units)	Potential‡ (units)
Dairy	1 cow	16	23	21	65
Beef cow (calf sold)	1 cow	100	165	250	300
Beef cow (calf fed)	1 cow	70	115	150	175
Steer calves	1 feeder	210	310	415	625
Short-fed cattle	1 feeder	310	500	625	825
Hogs§	1 litter	90	125	165	215
Feeder pigs	1 pig	1,400	2,100	3,100	4,000
Sheep, farm flock	1 ewe	415	625	1,250	1,400
Feeder lambs	1 lamb	2,775	4,150	6,250	8,000
Laying hens	1 hen	1,775	2,500	3,550	7,500

*One-man equivalent is assumed to be 2,496 hr or an average of 48 hr per week. Labor inputs do not include time for harvesting of forage or other feeds. Source: Planning Your Farm Business, Department of Agricultural Economics, University of Illinois, Urbana, Illinois, 1960.

†Estimates are based on recorded accomplishments of farmers in the corn belt.

‡Estimates are based on effective use of structures and equipment that are readily available on the present market and farmers with high but not exceptional managerial ability.

§These data assume the marketing of 7.5 hogs per litter.

TABLE 2. ESTIMATED LIVESTOCK INCOME THAT CAN BE PRODUCED BY ONE-MAN EQUIVALENT UNDER SPECIFIED LEVELS OF EFFICIENCY AND DEGREES OF MECHANIZATION*

		Income over cost per unit†				Total income over costs produced by one-man equivalent‡			
Enterprise	Unit	Low	Average	High	Potential	Low	Average	High	Potential
Dairy	1 cow	\$123.25	\$118.00	\$118.00	\$112.75	\$1,972	\$2,714	\$3,658	\$7,329
Beef cow (calf sold)	1 cow	8.03	7.50	7.50	6.45	803	1,238	1,875	1,935
Beef cow (calf fed)	1 cow	22.30	21.25	21.25	19.15	1,561	2,444	3,188	3,351
Steer calves	1 steer	17.38	16.85	16.85	14.80	3,650	5,223	6,993	9,250
Short-fed cattle	1 feeder	8.68	8.41	8.41	7.31	2,619	4,205	5,256	6,031
Sheep	1 ewe	6.51	6.30	6.30	5.98	2,702	3,938	7,875	8,372
Hogs	1 litter	34.18	33.12	33.12	31.55	3,076	4,140	5,465	6,783
Poultry	100 hens	59.25	48.75	48.75	43.50	1,052	1,219	1,731	3,262

*Data are for midwestern conditions and are based in part on budgeting information contained in R. A. Hinton's Farm Management Manual AE-3349, department of agricultural economics, University of Illinois, Urbana.

†Costs include a charge for all inputs except pasture and labor (See AE-3349 for pasture requirements). The terms low, average, high, and potential refer to levels of efficiency an mechanization as described in Table 1.

‡Estimates are based on the productive capacity of farmers with high but not exceptional managerial ability.

TABLE 3. ESTIMATED CAPITAL REQUIREMENTS PER UNIT OF LIVESTOCK FOR SYSTEMS COMPRISING SPECIFIED DEGREES OF MECHANIZATION*

Enterprise	Unit	Capital per unit for livestock, feed, and miscellaneous	Capital for low mechanization		Capital for high mechanization		Capital for potential mechanization		Percent increase in total capital to go from low to potential mechanization
			Buildings and equipment	Total†	Buildings and equipment	Total†	Buildings and equipment	Total†	
Dairy	1 cow	$400	$300	$700	$350	$750	$400	$800	14
Beef cow (calf sold)	1 cow	260	50	310	55	315	65	325	5
Beef cow (calf fed)	1 cow	375	70	445	80	455	100	475	7
Steer calves	1 steer	195	55	250	60	255	80	275	10
Short-fed cattle	1 feeder	258	28	286	30	288	40	298	4
Sheep	1 ewe	25	23	48	25	50	28	53	10
Hogs	1 litter	235	200	435	220	445	250	485	11
Poultry	100 hens	225	600	825	700	925	750	975	18

*These estimates are based on requirements for commercial-size operations in the corn belt. They involve shifts in enterprise as shown in Table 1, e.g., capital requirements for a dairy system having low mechanization are based on a 16-cow herd while requirements for potential mechanization assume a 65-cow herd.

†Land is not included in these investment totals.

TABLE 4. TOTAL CAPITAL REQUIREMENTS, EXCLUDING LAND, THAT ARE NEEDED TO PROVIDE ONE-MAN EQUIVALENT WITH FULL-TIME EMPLOYMENT WITH A FULLY MECHANIZED SYSTEM*

Enterprise	Size of enterprise (number)	Capital Requirements			Percent for buildings and equipment
		Livestock, feed, miscellaneous	Buildings and equipment	Total	
Dairy cow	65	$26,000	$26,000	$52,000	50
Beef cow (calf sold)	300	78,000	19,500	97,500	20
Beef cow (calf fed)	175	65,625	17,500	83,125	21
Steer calves	625	121,875	50,000	171,875	29
Short-fed cattle	825	212,850	33,000	245,850	13
Sheep	1,400	35,000	39,200	74,200	53
Hogs (litters)	215	50,525	53,750	104,275	52
Poultry	7,500	16,875	56,250	73,125	77

*Assuming the situation described as potential mechanization in Table 1.

cost of production resulting from mechanization. As indicated in Table 2, income over costs produced by one man equivalent is $1,972 for the manually operated dairy enterprise compared with $7,329 for the fully mechanized system.

Similar increases in income per unit of labor can be realized from use of efficient work methods and mechanical equipment in other livestock enterprises. With beef cows or sheep, gains in productivity of labor result almost entirely from improved work methods and facilities designed specifically for convenience in handling livestock. In enterprises in which materials handling comprises a major part of the work load, such as the fattening of cattle or hogs, mechanical equipment is chiefly responsible for increasing productivity per worker.

Labor-saving methods, equipment, and structures provide the vehicle which makes possible large increases in productivity of labor. This does not, however, insure that farmers will secure increase in income proportionate to their ability to handle volume. Labor-saving devices cannot help to increase income unless funds are also available to purchase the livestock, feed supplies, and other production items needed to enlarge a business. Total capital needs must be analyzed carefully and provided for in advance of expanding an enterprise to guard against creation of an "equipment-poor" situation.

Capital needs are only 4 to 11 percent greater in fully mechanized systems for beef cattle, sheep, and hog enterprises than in those which rely chiefly on manual methods for handling the work load (Table 3). Dairy and poultry enterprises require increases in total capital of 14 and 18 percent, respectively, to shift from low to fully mechanized systems. Livestock and building capital comprise the bulk of investment and neither is affected by the level of mechanization or degree of efficiency with which facilities are used unless perhaps in an adverse way. It should be recognized, however, that the significance of capital investments is not wholly revealed by percentages. Operation of livestock enterprises involve short-term (livestock and feed), intermediate (equipment), and long-term (buildings) capital. An outlay for feed may be returned within a few days after it is made, while an investment in equipment may require ten years to recover. The proportion of intermediate and long-term capital varies from about one-eighth with short-fed cattle to three-fourths of the total for poultry (Table 4).

Not all farmers can take advantage of the techniques that are available to increase labor productivity. Existing facilities may be so rigid as to prohibit economical remodeling of buildings and lots or addition of mechanical equipment. Further, the number of livestock producers will continue to decline with the adoption of labor-saving methods.

Projected income potentials within the capabilities of one-man equivalent vary considerably among enterprises, ranging from less than $2,000 for an extensive enterprise such as beef raising to more than $9,000 for enterprises such as beef fattening which can be largely automated (Table 2). These differences among enterprises may change as time alters basic relationships. The significant feature of the data in Tables 1 and 2 lies in the differing results within a given enterprise from mechanization or changes in work methods. These variations in income potentials within an enterprise are relative and are likely to maintain their relationship regardless of the level of prices and costs. The proportionate effect of an engineered farmstead on the earning power of farm labor is therefore quite large for all enterprises.

BALANCING COSTS AND RETURNS

Deciding among the various alternatives of equipment, buildings, or even complete farmstead units requires a quantitative measurement of the costs and benefits of the alternatives. The preceding examples provide illustrations of the kind of measurements that are needed. Once data are available, it is desirable to have an easily manageable method to reduce the costs and benefits to a single answer expressed in dollars of net return. The typical farm-planning budget can be used to test alternatives, but manipulation of a budget of an entire farm business is sometimes so unwieldy as to discourage the farmer, or at least to place quite a restriction on the possibilities that he is likely to test.

The partial budget is a short, simple, and relatively accurate analytical tool for checking annual costs and returns. It is well suited to the examination of alternative facilities such as buildings or equipment or methods of operation||||. This type of budget is called "partial" because it permits omission from the analysis of all items, except those which actually change among alternatives under consideration. For example, if mechanical equipment is used to expand a livestock operation, but total labor input remains the same under both sys-

(Continued on page 648)

||||For an example of the use of a partial budget, see Van Arsdall, R. N. Selecting materials-handling equipment, *Economics for Agriculture,* Department of Agricultural Economics, University of Illinois, FM-6, June 1960.

Capital Requirements of Engineered Farmsteads

Douglas F. Graves

AMERICAN agriculture is in the middle of a far-reaching scientific and technological revolution. This revolution has been in progress for two decades, but at an accelerated rate during the last few years. Agriculture is changing from a way of living to a way of making a living. It is changing from a business of arts and crafts to a business undergirded with large amounts of science and technology. Productivity per worker on commercial farms is increasing phenomenally. Still greater increases lie ahead as we substitute more capital and technology for labor.

Agriculture — An Expanding Industry

Entirely too many people think of agriculture as a declining industry. Nothing is farther from the truth. American agriculture is an expanding industry in every important respect except one: the number of people required to operate farms.

Although only a small share of our total population is engaged directly in farming, the agricultural industry is big and basic. Out of the 68 million people employed in America, about 26 million work somewhere in agriculture. Eight million work on farms, seven million produce goods and services purchased by farmers and eleven million process and distribute farm products. In addition there are about one-half million scientists working in the general field of agriculture. Hence almost two-fifths of the total labor force is engaged in agriculture and related work.

The decline in farm population, although viewed with alarm by some politicians and rural fundamentalists, is a sign of a strong agriculture. Total agricultural output in the United States has increased two-thirds in the last two decades, while the numbers of the farm workers have been reduced some three million. This means that production per worker has doubled in the last twenty years. This is a remarkable increase in production efficiency. It can be matched by no other major sector of the American economy.

One farm worker in America now feeds and clothes himself and 25 others. Just a generation ago in 1930, he fed and clothed himself and 9 others. A century earlier he fed and clothed himself and only 3 others.

Progress of this kind can be continued, only if we have capable and well-informed farmers who are properly financed. We will need fewer farmers in the future, but they will need to be better farmers.

No longer can we regard agriculture as simply plowing fields, picking corn and raising hogs. "Agribusiness" is the name coined for the new agriculture. It is the blending of business, industry, science and education into agriculture and the rural communities. Today's new methods of production, processing and marketing of agricultural products are the results of this blending.

Industry depends upon agriculture as a customer. In contrast to a generation ago when farmers were producing most of their own fuel, power and fertilizer, industry is now furnishing farmers each year (according to Chas. Pfizer & Co., Inc.):

(a) 6½ million tons of finished steel, more than is used in a year's output for passenger cars

(b) 45 million tons of chemical material, about five times the amount used in 1935

(c) 18 billion gallons of crude petroleum, more than is used by any other industry

(d) 285 million pounds of raw rubber, enough to make tires for 6 million automobiles

(e) 22 billion kilowatt-hours of electricity, more than enough to serve the cities of Chicago, Detroit, Baltimore and Cleveland for a year.

The new agriculture is emerging with breathtaking rapidity. The transformation is taking place so quickly that we are experiencing difficulty in adjusting to it sociologically, politically and financially.

In this setting it is particularly important that we give every emphasis to the development of proper credit for the new agriculture.

Credit Needs of Modern Agriculture

The credit needs of agriculture can be divided into three classifications, each of which is intended to serve a useful and legitimate purpose in financing agriculture:

(a) Short-term credit for production purposes is basically a commercial bank function.

(b) Intermediate-term credit is designed for the financing of such capital assets as machinery, farm improvements, breeding stock, etc., the terms of which usually run from two to five years with repayment being made on an amortized program. In many situations the local banker can supply only a portion of the intermediate credit that is needed in the community, and the borrower must look to other sources of credit such as implement companies, farm building and equipment suppliers, and others.

(c) Long-term credit with maturities from 10 to 40 years is extended on real estate. This type is offered to a limited degree by commercial banks, but primarily this is a function of institutional investors.

Farmers have not lacked sources of credit in spite of the revoluntionary changes which have taken place in agriculture. We know that any form of credit that is worthy is inevitably going to be extended — if not by commercial banks, then by either private lending agencies or by the government itself. If the credit is worthy, it will not for long remain unextended. One of the best examples is the case of installment credit. When commercial banks failed to provide adequate financing for the mass production of automobiles and other types of consumer goods, finance companies intervened to meet the need. In recent years bankers have seen their mistake and have tried to regain this business. We have been successful in part, but the finance companies are here to stay.

The history of the production credit associations is well known. While there may have been some social or political aspects in connection with their creation and the type of loans originally made by them, by and large these loans were good loans and were repaid. Most of the credit they have extended through the years has been worthy credit and should have been provided by commercial banks. Prior to 1924 there was no competition from the so-called federal agencies. Today these agencies make approximately 30 percent of the total loans used for production purposes.

To the extent that we allow other lenders to invade the function of a commercial bank, or to the extent that we rely upon the government to provide credit we should supply, the strength and independence of the commercial banking system is weakened.

The country banker is well-equipped to provide a coordinated program for financing agriculture. Rare is the country banker who does not have affiliations with institutional investors for long-term credit. He has his own and other resources for intermediate-term credit, and for temporary periods his own short-term credit resources can be supplemented by his correspondent bank.

The farm lender and farm borrowers are finding it necessary to deal in larger loans than was customary only a few years ago. This is due in a large measure to *(a)* larger farm units, *(b)* inflationary prices and *(c)* purchase of supplies which heretofore were produced on the farm. Today there are opportunities for the efficient farmer to enlarge his operation. Failure to use a well-designed credit program to achieve this end may mean the difference between his success or failure in the competitive struggle.

We know that the past year has been very difficult for some farmers and they have lost

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the race. However, farm records indicate that many farmers have done well. We also know that a group called "part-time" farmers have also done well, not from farm income but from income from other sources.

' Now comes the trouble group, that large group of farmers in between the top and the bottom. Some of this group will find part-time work off the farm, and why shouldn't they? Farm records show and we know that a grain farmer works less than 150 days per year. Should he expect to live twelve months and work only five months? Part of this large center group is finding it impossible to continue farming. They don't have and can't get the land, equipment or capital, and in many cases they don't have the management to compete.

Still other farmers in this middle group have the managerial ability if they had the land and capital. It is this group that must be helped. If they are to be helped, there are three groups of individuals who are in a position to help them:

(a) The country banker
(b) The supplier of the goods and services to agriculture
(c) The farmer.

Let us look at each of these and see what part they play.

The Country Banker

Scientific advances in agriculture have made it difficult for many bankers to keep abreast of the changes. In certain situations this has resulted in their unwillingness to finance the application of the new technology. Employment of technically trained agriculturalists has assisted in keeping bank management informed. Unfortunately, in many cases, bank management has continued to finance agriculture and to extend credit on the same terms as in the past. In situations where banks have failed to provide the amount of credit needed, government-sponsored credit agencies and industry have stepped in to supply capital for livestock, feed, fertilizer, equipment, etc.

We cannot overlook the fact that in some areas there are special conditions which make the problem of the banker especially difficult. These are the areas where, because of inadequate land resources, it is not possible for the farmers to adapt modern production methods to the type of farming which has been traditional. In such areas, the problem may be one of developing a more extensive type of farming by shifting some resources out of crop production. The excessive or wrong use of credit may tend to postpone a necessary agricultural adjustment and may react to the future disadvantage of both the farmer and the lender. This has been the unfortunate consequence of some of our agricultural programs in recent years.

Bankers, by their lending policies, inevitably exert an influence on agriculture. In so doing, they have both opportunity and responsibility. In our soicety opportunities exist over a period of time only where there are individuals who are willing to assume the responsibilities. Which term one chooses depends on whether he is activated by obligation or by challenge.

Opportunities can be defined in terms of service to agriculture by the directing of funds toward more stable production of the right products and toward the more efficient use of agricultural resources. Some will say that this objective should be the result of production decisions made by farmers and policy decisions made by the government. We bankers often tend to justify our lack of concern for these problems by arguing that our business is to lend money. Therefore, some feel we should remain neutral with respect to what is produced, how it is produced or how it is marketed. Actually, we cannot remain neutral in decisions affecting agriculture.

When a banker grants a loan for one purpose, he automatically limits the funds available for other purposes. This rationing of capital automatically guides and directs production decisions. Bankers are in a position of strong influence in the agricultural community by the very nature of this rationing. The question which each of us must ask is whether this influence will be positive or negative and whether or not it will come from an informed position.

Another problem with which the country banker is faced in recent times is the fact that the need for credit has developed at a faster rate than new deposits have been generated. The country bank's loan-to-deposit ratio may be the reason that the bank is unable to take care of its customers even though the loan request is not in excess of the bank's legal lending limit.

Today many farmers need more credit than can be supplied by their local banks, and their bankers in some cases are not helping them secure the additional credit. In industry and other business, it is an accepted practice to use bank credit from a few weeks to an entire year. Agriculture must develop a system of financing similar to industry which will permit farmers to use a revolving type of credit or an open-end mortgage for year-round financing. Farmers need a line of credit to draw on as it is needed during the year to purchase feed, livestock, fertilizer, machinery, labor, new buildings, etc.

If this is the type of credit needed to put the new technology to use, it will be furnished by someone, and if the local banker wants this business, he must be set up to handle it.

If the country banker is to provide a complete credit service to his community, he must be prepared to accommodate a deserving customer. If the loan request is in excess of his legal limit, or the bank is faced with a temporary situation in which it is not in a position to make additional loans because of shortage of funds, the banker must elect to do one of the following:

(a) Turn the loan down
(b) Hold the borrower within the bank's legal limit
(c) Loan what he can and direct the borrower to a neighboring bank or other lenders for the balance
(d) Call upon his city correspondent.

No comment is necessary in the case of item *(a)*, but let us take a look at each of the other situations and see how they operate:

Bank's Legal Limit

When he is held down to fit the bank's lending limit, the customer's economic progress is stifled, and it is only a matter of time until some other bank will offer sufficient services and take the account.

Neighboring Banks

When a customer is sent to another bank for a part or all of his loan, it tends to encourage the customer to divide his business. The originating bank's relationship with the borrower is weakened, and eventually it may terminate. A greater problem exists when no one bank controls the credit. An individual engaging in loan transactions with several banks may obligate himself far beyond his ability to repay. Better credit controls result if the originating bank handles the borrower's entire credit, either through neighboring banking friends who may not be inclined to take a competitive advantage, or through the originating bank's correspondents.

Some large borrowers are directed to government-sponsored agencies because their credit needs are too big for the local banker. By doing this, the banker hopes to at least maintain his deposit relationship with the customer. Where only part of the bank's service is available, there is always the danger that some other bank will offer complete services and take the customer. The new bank may be large enough to handle the entire loan, or it may have made arrangements with a correspondent to help service the loan. The customer has been lost to the bank that cannot give complete service because he would prefer to do all of his business in one place.

The City Correspondent

Correspondent banking is the most distinctive feature of the American system of banking. If we are to preserve the independence of this system, we must preserve and expand cooperation between large and small banks. Correspondent banking, when working at its best, brings to the country bank all of the services of the city bank, including credit advice and lending assistance. It provides efficient and flexible banking services for rural as well as city areas.

In 1953 the American Bankers Association conducted a study on the practical operations of the correspondent banking system. A questionnaire was sent to over 3,000 country banks. They were asked the kind of services the country banker needed most from their city correspondents. More banks indicated that they needed help on loans than any other service offered by the city banks.

A similar study was made again in 1959, and this time the Association sent a questionnaire to a cross section of banks with assets under $7,500,000. In general, the country banker expressed his satisfaction with the functioning of the correspondent system, but emphasis was once more placed upon the need for better loan cooperation from his city correspondent.

In response to the question, "What recommendations would you make for improving your correspondent's bank loan policies and

procedures?" some of the answers were as follows:

(a) "Too often the city bank maintains the metropolitan viewpoint of reliance only on financial statements and audited reports."

(b) "Many correspondent banks have no one, or very few individuals, on their loan committees who are well informed on loans in areas which are 50 percent agricultural."

(c) "Send qualified loan officers to consult with us and set up definite standards that are practical for participation with this institution on loans."

(d) "Provide a service for carrying agricultural loans during months of heavy demand."

City correspondents differ widely in their policies and willingness to work with country banks on agricultural and other credits.

Referring again to the three groups that are going to influence the amount and type of credit farmers receive, namely, banker, supplier, and farmer, the second one to consider is the supplier.

The Supplier

The suppliers are the building and machinery salesmen, feed dealers, etc. They have done an excellent job of research and developed the tools faster than the farmers and bankers were ready to accept them. However, in their desire to sell, many of these suppliers have extended credit far beyond the farmer's ability to pay. Salesmen have talked farmers into programs that they could neither manage nor finance. As a result, many farmers are in trouble due to hit-and-miss methods of expansion and credit.

In addition, several farmers' organizations have made arrangements with non-bank lending agencies whereby the dealer or store will give book credit until a given date, at which time the lending agencies will take over and make a loan out of the book credit. This is wrong. Credit should be based on the individual's ability to repay, not on his willingness to use book credit.

The salesman who wants his customers to obtain sound credit, must help the farmer develop his livestock and farming program within his managerial and financial capacity. When such a program is developed, a banker will be much more likely to go along.

The third member of this team is the farmer.

The Farmer

Farmers have never been taught how to use credit. Because so many farmers dislike the formality of signing notes at a bank, salesmen and merchants have extended them "book credit." This has resulted in the loss of cash discounts, interest, and carrying charges. The margin of profit is so low in agriculture today that, if a farmer is paying these extras, he may be losing a good share of his profits.

Farming is big business and farmers must act like businessmen. This means they will need records, not only of income and expenses, but also an analysis of the various parts of their farming operations. If they are to borrow large sums, bankers will want to know what they have done, how they have done it and see the results on paper. In other words, farmers will find it increasingly difficult to borrow large sums of money unless they are prepared to furnish the necessary records.

Recently I was called into a situation in northern Indiana. The farmer wanted to expand his cattle feeding program. Before I had a chance to ask, he had his records out. He was a member of Purdue University's farm record-keeping association. He knew what his rate and cost of grain had been, the cost of putting up silage, etc. In a matter of an hour we had approved a three-year loan. In addition we had made suggestions for a reorganization of his farm borrowing. Farm records are a "must" for both owner-operators and for tenants.

In the past many of us have overlooked the tenant as a prospective customer for capital improvements. The tenant-operated farm does present many problems of which the lack of livestock facilities is one of the most serious.

Landlords are seldom interested in making major improvements when they do not receive a direct benefit from the improvement. Under the customary cash-grain lease, the landlord receives a return from the crops only, and as a result he is not particularly interested in making improvements from which the tenant will receive the entire benefit. The landlord may be interested in improving the farm only to the extent that he can attract and hold the type of tenant who will operate the farm in a manner consistent with the landlord's objectives for the farm.

The type of investment made by the landlord will depend upon the opportunities open to him. The rigidity of custom and the opposition of tenants toward paying a building rent has limited the type of investment made by the landlord. The rigidity of rental arrangements has often resulted in the landlord's making improvements which have not been based on the needs of the farm nor the marginal returns of the investment, but rather upon the opportunity of the landlord to invest where he could expect the greatest return on his capital.

As long as the investment opportunities of the landlord are limited and a workable method of permitting the tenant to share in making the necessary investment is not developed, there will continue to be a loss to the tenant and landlord.

The seriousness of the problem concerning the lack of farm improvements is noted in response to a recent questionnaire to a group of Iowa tenant farmers. Sixty-seven percent of this group indicated that lack of improvements was their main problem, while only 3 percent listed the lease itself as a problem. One explanation for the small number concerned over the lease may be due to the lack of constructive thinking by farmers regarding leasing arrangements. Farmers and landlords have looked upon the lease as a method of dividing grain and determining cash rents. Little or no consideration has been given to the possibilities for improving other farm problems through adjustments in leasing arrangements.

However, some landlords and tenants have worked out programs whereby the tenant on a grain-share lease can make investments in capital improvements. Recently our bank participated in a loan to a tenant farmer for the mechanization of his livestock-feeding operation. This loan is just as secure and just as sound as if it had been made to an owner operator. The tenant obtained from the landlord an agreement that should the lease be terminated, the tenant would be paid for the unusued value of the improvements.

This type of loan will not be commonplace. Until this information is available and usable, landlords will have no sound basis for compensation for unexhausted improvements made by tenants. It should be noted that several companies represented here have done an excellent job in using this approach.

It is also possible to make a loan for a fixed asset on leased ground by obtaining from the fee owner the right to dismantle the structure and move it to a new location.

Farm buildings are often taken for granted and may even be considered as a burden that must be tolerated. In reality, buildings have an important function in the business of farming and instead of being static, they should be a dynamic force influencing returns from the farm. On many farms today it would be more economical to abandon all the buildings and start from scratch.

Banks are being asked in increasing numbers to finance various forms of farmstead mechanization. Many of these loans are too large for the local bank and it is necessary that a city correspondent help provide the funds. I have been called on many occasions to consider this type of loan. When these requests come, it is almost always necessary to wait several weeks because no one — the farmer, the local banker or the equipment salesman — has given any real consideration to future planning.

The first consideration is the preparation of a budget. A budget is invaluable for an intermediate-term loan because

(a) It indicates the repayment capacity of the borrower.

(b) It serves as a guide for setting up repayment dates.

(c) It shows the money requirements for the entire farm for the full period of the loan.

All too often when plans are made for farmstead improvements, no plans are made for anything except the individual improvement. The following questions should be asked before going ahead with a loan:

(a) Is this a part of a planned, engineered program, or is it a hit-and-miss expansion with high-cost, cheap construction and makeshift equipment?

(b) What will the complete program cost and when will it be completed?

(c) What will the proposal mean to the total farm program? Will it mean more borrowed funds for additional livestock, poultry, etc.?

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Future Farmstead Power Requirements

H. N. Stapleton
Member ASAE

FOR most of two days of this conference, we have concerned ourselves with the technology of production engineering for the farmstead. As we examined the means for combining shelter, environmental control, and operating equipment into systems, we sought economical methods for energy conversion. As we discussed the equipment for these systems, we were concerned with the use of mechanical and electrical energy to improve the productivity of labor. At no time was the availability or the requirement in substitute energy questioned seriously, nor was the mechanical efficiency of any specific item of equipment of great concern. It was inferred that the power requirements of these tools of production and the cost of energy for their operation is a relatively minor economic item. This is relatively true, but knowledge and management need to be applied to make it so.

Raw or primary energy as such is relatively inexpensive. The systems using electrical energy, which have been discussed may possibly use 10 kwh per month per $1,000 of capital investment. For a five-year life installation, the annual fixed costs of about $250, along with the annual energy cost of about $2.50, show a 100 to 1 ratio. If either the useful life or the energy use is increased, the ratio is reduced, but, in general, the greater share of costs in a substitution for labor goes to capital rather than to the substitute energy. It will also be noted that, on a percentage basis, savings in initial investment are much more effective than savings in energy cost in reducing over-all operating expense.

In the usual condition, the farmstead is an integrated operation and its total power requirement is developed from the requirements of several areas. For our purpose it is easiest to designate them as:

- Materials handling and processing, including field crop production and harvesting
- Environmental lighting, heating, and cooling
- Maintenance of plant
- Residential.

From the total power requirement of the farmstead, in horsepower and in kilowatts of electrical demand, or from the requirements of individual items of equipment, the costs of power requirement are related to:

- Capital charges for rated capabilities
- Service costs affected by reliability
- The energy conversion efficiency of the power unit
- The mechanical efficiency of the utilizing means.

At the farm, these items of cost of power requirement are balanced to take into account the actual degree of integration between the livestock operations and the other activities of the farming operation. When the same labor without individual specialization performs all of the work, there is usually less separation and specialization in the equipment. With intensive operation in one enterprise, its specialized production tools attain individual power plants, its power requirement is separated into automated increments, and the operator attains supervisory status.

For the intensive enterprise, electrically controlled equipment is usually best adapted to automatic or push-button operation. If electrically powered, these items usually require only limited supervision and servicing. The general condition which appears to have limited electrical automation is the capital cost of power requirement supplied through single-phase service. Aside from copper and motor costs, there are usually arbitrary limits on motor horsepower, in addition to the general misunderstanding at the farm of the manner by which a demand-use power rate can be made to work favorably for both the user and the power supplier.

Both the farmer and his power supplier seem to have voltage and horsepower trouble. The farmer usually is unable to project or specify the conditions of demand-use. With three-phase service unavailable, he thinks of electric power as desirable for water pumps, refrigeration, and residential use, and receives service on a modified residential rate. The power supplier's representative will propose a 400-ampere service to a large user, rather than propose service at 480 volts. Irrigation pump service at 2400 volts is an unlikely topic for discussion in farm electrification and utilization. However, this situation does cause farm operators to turn to other sources for heat, and to the internal combustion engine for most power requirements above 7½ hp. Probably it cannot be said that stagnation, and not saturation, has been reached in farm electrification, but the trend seems to have been set by other forms of power, and a greater share of the increased farm use of electricity has gone to the residence to improve the standard of living of the family than as an input to farm production.

The technological key to satisfactory industrial power development on the farm seems to be an understanding of the requirements of a good demand-use, or load factor by both the user and the supplier. Electrical demand is analogous to rated horsepower in a tractor. The demand charge represents the investment cost required to obtain this rated horsepower. To develop good demand-use in tractors, implement manufacturers have developed full lines of easily mounted and dismounted equipment. The combination of electrical machines operating at one time produces electrical demand. When electrical use becomes 300 kwh per kilowatt per month or more, effective and economical use is being made of the facilities paid for in the demand charge, and the energy charge is favorable to the user and profitable to the supplier.

Connected electrical horsepower and demand are by no means identical. If the farm has two tractors, but only one operator available for field work, the demand on tractors cannot exceed 50 percent of available or "connected" horsepower. Similarly, a managed sequencing of operations can control electrical demand as a fraction of connected load to manage the unit energy cost for electric service.

Management can therefore permit any reasonable power requirement in individual pieces of farmstead operating equipment. For instance, a fully automatic milking parlor which required only supervision, instead of operator participation, could conceivably tolerate up to 50 hp if this amount of power were required for its operation. Baled-hay storages in pole-frame livestock structures could use a stowing device with a power requirement at least equal to the power requirement of a chopped hay blower. Manure removal with field spreading, by hydraulic flushing, sequenced and directed, apparently could earn a 35-50 hp power requirement, balanced against the labor and equipment input used at present in handling the tonnages involved in most livestock operations. In these three examples there is a possible 125 connected horsepower, but no reasoning of management or availability of labor indicates that all should be operated at the same time. The electrical demand can be taken as that of the largest item of the three. While management must see to adequate power requirement in equipment, it certainly has the prerogative of programming both the schedule for labor and use of equipment.

The other management factor in the use of electric power is reliability. Peculiarly, because alternatives are not very practical, service must be available 100 percent of the time. Power failure from whatever cause is a disaster. A standby generating unit is therefore an integral part of the total equipment. Its capacity should be such that it can carry operations through at least a seven-day outage on a split load basis; that it can start the largest motor in the operation, and that its rating is at least one-half of normal demand. Since it is easier to plan before than during an emergency, a detailed operating plan for the use of this standby unit should be known to all concerned.

For the internal-combustion engine equipment for the farmstead, it can be presumed that an operator will be required, and that this type of power will not be used by any machine which would be electrically powered if used in any other industry. In gen-

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Electric Power Supply for Agriculture

Virgil H. Herriott

AGRICULTURE is the largest power-using industry of our country. A third of a century ago, agriculture's total use of power was greater than that of all other industries combined. Recent Department of Agriculture figures show that farms are using over 250 million horsepower, exclusive of automobiles and home appliances. Only 10 million of this, or about 4 percent, is electric power, fifty million is in stationary gas engines, 87 million in tractors, 88 million in trucks, and 16 million in harvester-threshers.

As manager of a rural electric system that is part of the evergrowing electric industry, I am keenly aware of the potential application for electricity that exists in modern agriculture. Electric power can meet many, if not most, of the fixed-location power requirements of agriculture. The 50 million horsepower in stationary gas engines alone is readily adaptable to electric service and represents five times the amount of horsepower being served by electricity today. Recognizing this, I am concerned about whether or not electric power suppliers are aware of this potential and accept this opportunity to serve these larger horsepower requirements.

To adapt these large horsepower requirements to electricity, farmers need an abundant supply of electric power at the lowest possible cost, available in the quantities and at the locations that meet their needs and equipment designed and installed which will make the best use of electric service available.

All of this requires service policies related to the availability of power and rates that encourage the maximum use of electric power, effective long-range power system planning, close coordination between power suppliers and those involved in research, education and manufacturing, and increased emphasis by power suppliers on assistance to farmers in the best application of electricity to their fixed-location power requirements.

Farm use of electric energy has been increasing at a rate more rapid than the rate at which the average use of electricity has increased for several years. Much of this increase in usage is attributed to home electrification, but it appears now, however, that the increase in use for farm electrification is beginning to accelerate at an even faster rate.

The amount of power used by farmers, or anyone else for that matter, is greatly influenced by the rates and service policies of the power suppliers. These have in many instances been maintained through the years without revisions and without regard for changing conditions. Many times, the service policies of the past, when applied to today's circumstances, discourage the consumer from moving toward the all-electric operation. There may have been some justification for these policies in the past, but the requirements of the future demand that we drastically revise the old limitations on the size and type of equipment that can be used by farmers without imposing rates and changes which discourage rather than encourage the widespread use of electricity. I doubt that we can eliminate rules and limitations completely, but surely they can be overhauled and updated.

A lot of rural power suppliers still will not serve a motor larger than 5 horsepower without so-called "penalty rates." Quick-recovery water heaters are outlawed in many places and many farm equipment items are not being used because of power suppliers' limitation on the size and type of equipment. Too many of our manufacturers report that a high percentage of the equipment they manufacture is equipped for power take-off operation, and this is primarily because adequate electric power is not available at proper rates to operate it electrically. There can be many different reasons for these restrictive policies and limitations, but it behooves all of us to use whatever influence we have to the end that those on the policy-making level will recognize the changing circumstances and the changing conditions and that these policies will be revised.

It was my privilege to address the American Society of Agricultural Engineers at its golden anniversary meeting in June, 1957. At that meeting, I talked about long-range planning for all-electric farming, with emphasis on the planning by the power system. I will not review all the things I said at that time, but I do want to pinpoint some of them.

First, there needs to be coordinated long-range planning between power suppliers and the people involved in research and education as it relates to improving farm operations. People in research and education need to know of the availability of power and the basis on which it is available. People involved in power distribution need to be informed of the needs for power requirements, not only now, but into the future as well. This kind of coordinated long-range planning should result in the farmer's needs being best met.

South Dakota rural electric cooperatives engaged in a series of long-range engineering plans a few years ago. Each cooperative studied the type of agriculture currently being carried on in its service area and projected the possible future electric power requirements based on the then known uses. An average use of 30,000 kilowatt-hours per year per farm was envisioned on many systems.

The next step was for the cooperative to plan, based on certain assumptions, how they could best provide for power requirements of this magnitude, together with estimates of what the costs might be. These studies have been important because they have provided a planning guide for the orderly and systematic expansion of the individual systems as the loads grow at a rapid rate. I can cite many instances where this type of planning has paid for itself time and time again. It has permitted the individual systems to minimize obsolescence, thus keeping capital investment at a minimum, yet providing adequate capacity at all times.

An interesting sidelight of our long-range planning was that, in the future, three-phase service would be readily available to a large percentage of farm consumers. On our own system it indicated that the future distribution system would provide a three-phase line to within two miles or less of nearly every consumer.

The availability of three-phase service should make it possible for many of the larger horsepower requirements of the farm to be readily converted to electricity. We believe that the availability of three-phase service will accelerate our rate of load growth and encourage the farmer to use more electric-powered equipment.

Neither long-range planning alone nor a revision of service policies and limitations will result in the proper solution for the future. Both must be undertaken with an attitude for improving the availability, quantity and cost of electric power to all farmers.

The current trend toward "high-speed" mechanization of some farm applications is giving many electric power suppliers cause for concern. Processing and handling large quantities of farm products in a short period of time calls for much larger horsepower than if these same requirements were spread out over a larger period. Some studies have shown that lower speed, longer time installation utilizing automatic operation will result in a much more efficient operation with less investment to the farmer. This also means that the electric power supplier can serve these loads with a lower investment and thereby make this type of electric service available to many more farms and at a lower cost.

There is a need for close cooperation and coordination between power suppliers and those involved in manufacturing, research and education. The proper design and application of farm equipment and methods, to be effective, must be developed in coordination with representatives of all of these groups. Utilizing the available talent and experience of these representatives will result in the most efficient and economical answer to the farmer's horsepower requirements.

The universities and extension services have carried on extensive education and assistance programs relating to new and

(Continued on page 649)

The author — VIRGIL H. HERRIOTT — is manager, Sioux Valley Empire Electric Association, Inc., Colman, S. D.

Manufacturers' Literature

Manufacturers' Literature selected for this issue consists of material which describes components, equipment or systems material especially adapted for Farmstead Engineering applications and has been supplied by the manufacturers in response to a request for such material from ASAE and the Farmstead Council. Numbers in parentheses refer to the firms listed in directory on page 636. Literature listed below may be obtained by writing the manufacturer.

BLOWERS

Centrifugal Pressure Blowers—1 p (2)

BUILDINGS AND BUILDING MATERIALS

Rib Roofing and Siding—4 pp (4)
Farm Roofing Manual—24 pp (4)
Pole-Type Farm Building Plans Catalog—20 pp (4)
Application Instruction for Alcoa Aluminum—kit (4)
Galvanized Steel Sheets for Roofing and Siding Circular—(6)
Galvanized Steel for Modern Poultry Houses and Equipment Circular—(6)
Selection and Application of Galvanized Roofing and Siding—Brochure, Form AZ138 (10)
Industrial Procurement Galvanized Steel Sheet Brochure—36 pp, Form AZ137 (10)
Steel Farm Buildings Catalog—12 pp, No. B-10059 (12)
Steel Buildings for Dairies Application Bulletin 65—16 pp (12)
Steel Buildings for Machinery Storage Application Bulletin 62—12 pp (12)
Straight-Wall Grain Storage and Utility Buildings Bulletin—No. AD-689M (17)
Curvet Farm Building Bulletin—No. AD-465 (17)
Metal Farm Buildings Brochure—8 pp, No. 1922 (20)
Hog Production Buildings—(20)
Steel Roofing and Siding Bulletin—12 pp (22A)
Do You Want to Cut Down Time and Work Around Your Farmstead?—Efficiency Engineering Bulletin (32)
Doane Ideas on Farm Buildings—96 pp, 4th Edition, price $3.00 (32)
Fir Plywood for Today's Construction Booklet—16 pp (40)
Fir Plywood for Farm Structures Booklet—12 pp (40)
Grain Storage Conversion Rigid Frame Structures Circular—(40)
Structural Alterations for Rigid Frame Structures Circular—(40)
Grain Storage Conversion 36' Clear Span Pole Barn Circular—(40)
Exterior Type Plywood Bulletin—6 pp (40)
Plans for Bulk Feed Bin Bulletin—6 pp (40)
Prefabricated Plywood Feed Bins Bulletin— 8 pp (40)
Bunker Silo Bulletin—(40)
Expandable Egg Cooler Bulletin—(40)
Life Cycle Housing Bulletin—8 pp (40)
Poultry Houses with Scissor-Type Nailed Trussed Rafters—Technical Bulletin 34 (51)
Nailed Trussed Rafters with Harboard Gusset Plates—Technical Bulletin 40 (51)
King-Post Nailed Trussed Rafters—Technical Bulletin 36 (51)
Nailed Trussed Rafters with Hardboard Gusset Structures—Technical Bulletin 33 (51)
Lok-Frame Steel Buildings Catalog—12 pp, No. 590 (53)
Beef Cattle Housing Plan Service—20 pp, Set LFP-B, price 25¢ (53)
Dairy Cattle Housing Plan Service—20 pp, Set LFP-C, price 25¢ (53)
Machinery Storage Plan Service—20 pp, Set LFP-A, price 25¢ (53)
Hog, Sheep, Poultry and General Purpose Plan Service—24 pp, Set LFP-D, price 25¢ (53)
All Steel Windows Bulletin (56)
Farm Structures with Built-in Insulation and Complete Ventilation Bulletin (56)
Aluminum Roofing and Siding Bulletin—No. R-851 (57)
Reflective Foil Insulation Bulletin—No. R-135 (57)
Aluminum Roofing Reflectivity Technical Service Bulletin No. 1—7 pp (57)
Roofing and Siding Guide—15 pp, No. R-29 (57)
Pole-Type Multi-Purpose Storage Building Plan —No. A-900 (57)
Pole-Type Loafing Barn Plan—No. A-936 (57)
40' x 80' Pole-Type Grain-Storage Building Plan —No. A-978 (57)
71' x 300' Pole-Type Grain-Storage Building Plan —No. A-985 (57)
Design Details for Glued-Nailed Trusses Plan—No. A-969 (57)
Aluminum Covered Pole Type Corn Crib Plan —No. A-995 (57)
Pole Building Details Plan—No. A-1004 (57)
Aluminum Nail Guide—No. R-295 (57)
Plastic Foam Insulation Circular—(62)
Sandwich Panel System Circular—(62)
Panel Fab Poultry Housing Circular—(62)
Profits in Poultry Land—8 pp, Form No. TP-36 (63)
From Cradle to Gravy—8 pp, Form No. TP-37 (63)
This Is the House That Jack$ Built—8 pp, Form No. TP-38 (63)
Thermopane for Solar Farm Buildings—12 pp, Form No. TP-48A (63)
Masonite Literature on Poultry, Hog and Dairy Buildings (71)
Pave Your Barnyard with Concrete—Booklet (87)
Galvanized Steel Roofing and Siding Brochure —16 pp (89)
White Painted Galvanized Steel for Roofing and Siding Circular—8 pp, No. 3 (89)
Galvanized Steel for Poultry Houses and Equipment—16 p Booklet (89)
How to Select and Apply Steel Roofing on Farm Buildings—32 pp, Book No. 1020 (89)
Steel Building Products for Construction—10 pp, Booklet No. 1013R (89)
Farm Buildings Bulletin—12 pp, No. 102-1-1 (90)
Cold Spots in the Sky Can Help Fatten Your Livestock—16 pp Booklet, No. 101-1-2 (90)
All-Purpose Farm Roofing Sheet Bulletin—8 pp, No. 101-1-1 (90)
Aluminum Standard Roofing and Siding Sheets —4 pp, Bulletin No. 8b/Rn (90)
Type 50 Utility Laminated Rafter Bulletin—4 pp, Form No. F4 (91)
Type 55 Utility Laminated Rafter Bulletin—4 pp. Form No. F5 (91)
Rilco Straight Wall Bulletin—4 pp, Form No. F-19A (91)
Asbestos Stonewall Board Folder—12 pp, No. 1395 (95)
Individual Barn Planning Service—(99)
Principles of Poultry Housing for Quality Egg Production—6 pp, Farm Facts, Ref. Poultry Housing (101)
Housing for Quality Hog Production—20 p Reprint (101)
Facilities for Handling, Preserving, Storing and Feeding of Ensilage and Hay—14 p Reprint (101)
When Is a New Farm Building a Good Investment?—8 p Reprint (101)
Steel Buildings for Beef Cattle Feeding Operations—6 p Reprint (101)
Your Farm in Full Color—8 p Broadside, No. F252 (101)
Can Your Buildings Expand to Meet the Need? —Broadside, No. F251 (101)
Need a Fire-Safe, Long-Lasting Farm Building? —Broadside, No. F249 (101)
Cattle Never Had It So Good—Broadside, No. F248 (101)
Now You Can Get All-Steel Weather Protection for Your Expensive Machinery at a Price You Can Afford—Broadside, No. F247 (101)
There is a Stran-Master Building for Every Farm Need—Broadside, No. F250 (101)
Gypsum Wallboard Technical Bulletin—16 pp, No. GW-1 (110)
Texolite Paint Products Technical Bulletin—4 pp, T-8 (110)
Lime for Masonry Mortar—4 pp, Technical Bulletin, No. L-20 (110)
Fireproof Asphalted Sheathing Technical Bulletin—4 pp, No. GS-16 (110)
Insulating Wool Bulletin—4 pp (110)
Northern and Southern Pole Type Poultry House Folder—No. ADUCO 71033-59 (111)
Machinery Storage Pole Buildings Folder—No. ADUCO 83843-60 (111)
Pressure-Creosoted Wood Folder—No. ADUCO 83300-60 (111)
Galvanized Steel Roofing and Siding Folder—No. ADUCO 30013-60 (111)
Loose Housing Brochure—16 pp, No. ADUCO 71025-59 (111)
How to Fabricate and Erect Panelized Farm Buildings—(114)

CONTROLS

Electric Motor Controls—70 pp, No. 5900 (41)
Marsh Gauges—14 pp (70)
How Others Do It: Switches Provide More Efficeint Grain Handling—84-420 (72A)
Control Information File (74)

CROP DRYING EQUIPMENT

Crop Drying with Heated Air Is Profitable—4 pp (2)
The All New Aero-Wagon Crop Drying System —4 pp (2)
Don't Guess—Use an Aerovent Moisture Tester —1 p (2)
Gas Fired Fan and Heater Unit Grain Dryer—2 pp (2)
Duct and Heavy-Duty Tubeaxial Fans—2 pp (2)
Direct-Connected Panel Fans—2 pp (2)
Pulley-Type Square Panel Fans—2 pp (2)
Hay Drying Manual—60 pp, $1.00 (2)
Grain Drying Manual—100 pp, $1.00 (2)
The Am-Dry Continuous Grain Dryer—2 pp (5)
Dryer Facts—Batch Crop Dryer Booklet—8 pp, No. AD-640M (17)
On-Farm Drying Pays Every Year Booklet—8 pp No. 1805 (20)
Stor-N-Dry Equipment Manual—16 pp (20)
Let's Talk About Your Grain—10 pp, Brochure (38)
Crop Drying Equipment Literature File—(44)
Crop Dryer Literature Catalog—(61)
Hi-Dri Hay Drier Booklet—12 pp, No. B-1001 (66)

ENGINES

Diesel Engine Brochure—8 pp, Form 8SA77 (30)
Power to Haul the Earth Economically—12 pp, No. 6SA32 (30)
Gasoline, Diesel, Air-Cooled and Liquid-Cooled Engines—Catalog Literature File (47)
Engine Bulletin—No. D-302 (47)
Engine Bulletin—No. D-310 (47)
4-24 Hp Engine Bulletin—(58)
3-56 Hp Engine Bulletin—(116)

FARMSTEAD WIRING

"Farm Electricity" Booklet—200 pp, Price $2.75 (27A)
Planning Modern Farm Wiring Booklet—20 pp, Price 25¢ (79)
Specifications for Farmstead Wiring Booklet—16 pp, Price 25¢ (79)

FASTENERS

American Nails—32 pp (9)
Colored Nail Chart—Form 6537 (9)
Nail Catalog—20 pp (22A)
Fastener Literature—(29)
Fastener Catalog—24 pp, No. 8-483 (48)
Nails and Spikes in Creosote-Pressure-Treated Southern Pine Poles and Timbers—Technical Bulletin No. 26 (51)
Farm Nails Sample Display Card—(51)

FEED PROCESSING EQUIPMENT

Pelleting:
Profit Potential in Pellet Milling—16 pp (5)
Principles of Pelleting—4 pp (5)
The Am-Dry Continuous Pellet Mill—2 pp (5)
Mixing and Grinding:
Am-Dry Batch Mixers—2 pp (5)
Mixing, Crimping, Cracking and Ear Corn, Hay and Grain Granulator Literature Kit—(25)
Roller Mills Prices and Literature—(46)
Dry Processing Equipment Catalog—8pp (102)

FEEDS

The Three Little Pigs Folder—4 pp (97)
High-Moisture Corn Bulletin—No. MH-110 (97)
Why Make Hay?—8 pp, Bulletin MH-108 (97)
Why Dry Grain Sorghum?—4 pp, Bulletin MH-109 (97)
Farm Profit Plan Bulletin—20 pp, No. MH-100-A (97)
A Comparison of the Feeding Value of Ensiled High Moisture, Artificially Dried and Naturally Dried Corn for Fattening Steers — 4 p Reprint (97)
Alfalfa-Bromegrass Haylage for Summer Feeding of Yearling Steers—5 p Reprint (97)
High-Moisture Sorghum Grain for Finishing Cattle—4 pp Reprint (97)
High-Moisture vs. Low-Moisture Corn for Fattening Cattle Receiving Supplements With and Without Stilbestrol, Dynafac and 3-Nitro—10 pp, Reprint (97)
Haylage Feeding Trials with Dairy Cattle—10 pp, Reprint (97)

FENCES

How to Build Good Farm Fences—Brochure (9)
A Practical Guide to Contour Fencing—4 pp (9)
American Fence Products—42 pp (9)
Welded Wire Fabric Calculator—Form 6606 (9)
Decimal Equivalent Card—Form 6252 (9)
Farm Fence, Gates, Posts, Accessories Booklet —18 pp, (22A)
How to Erect Farm Fence—24 pp, Booklet. No. WD-274R (89)

GATES

Aluminum Farm Gates Folder—Form No. 10602 (4)
The Aluminum Gate Folder—Form No. 10671 (4)

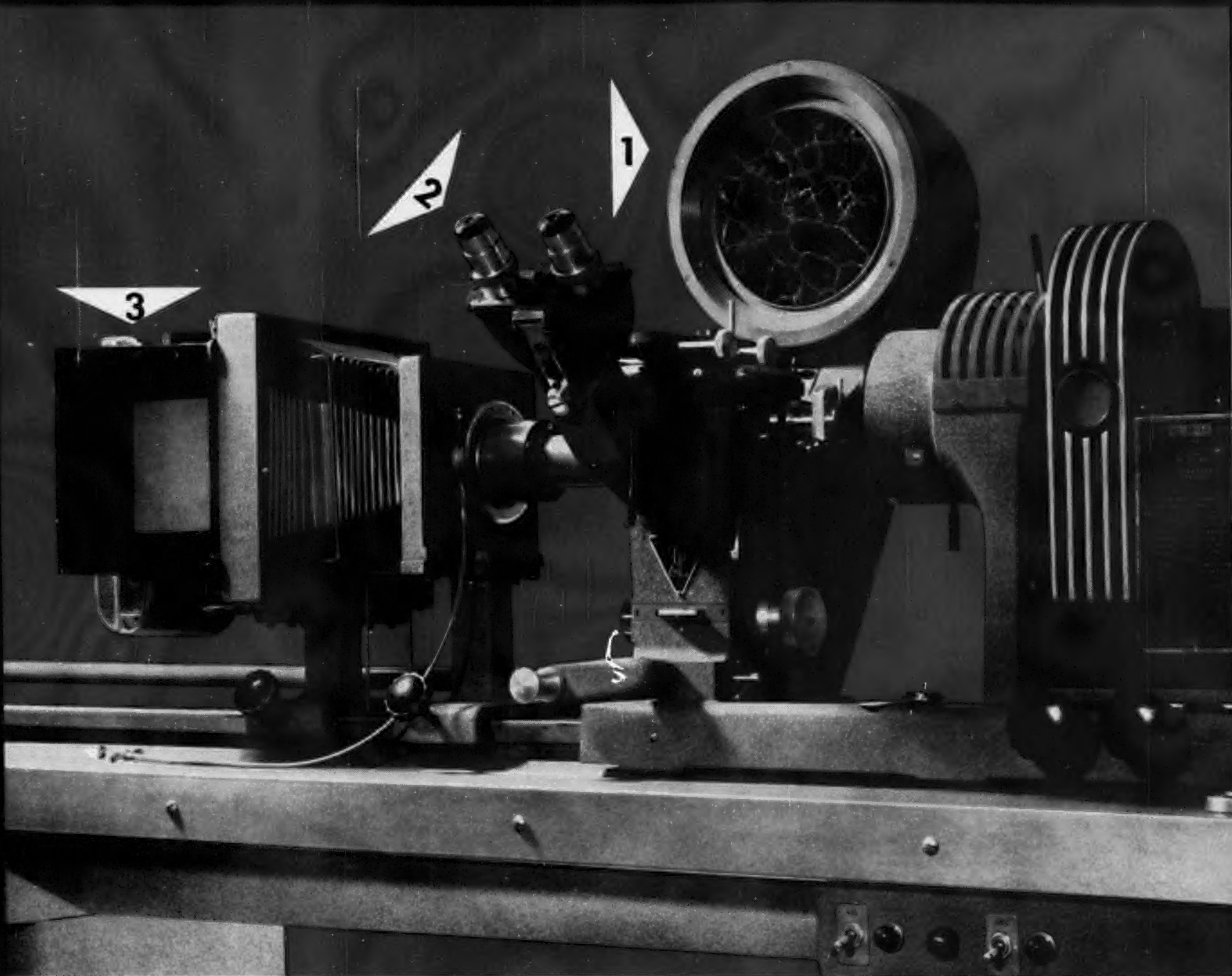
HYDRAULIC EQUIPMENT

Literature on Controls, Control Units, Control Valves, Pump Motors, Cylinders—(16)
Hydraulic Catalog—Literature File (34)
Pressure-Balanced Oil Hydraulic Pumps and Motors—No. 139D (49)
Fluid Power Equipment—No. 10-001 (49)
Dual-Vane Fluid Motors—No. DM-301A (49)
"Add-On" Hydraulic Control Valve V-34 Series —No. 12-160.1 (49)
Fluid Power Control Valve V-33 Series—No. 12-150.1 (49)
Hollow-Plunger Valves—No. 140B (49)
3600-A Series Pressure Balanced Gear Pumps—No. 10-150.1 (49)
2000-A Series Pressure Balanced Gear Pumps—No. 10-125.1 (49)
Literature on Hydraulic Components (60)
Needle Valves—7 pp, No. NV-1 (70)
Holedall Couplings—7 pp, No. H858 (77)
General Industrial Catalog on Hose and Tube Fittings— 128 pp, No. C-300 (113)

INSTRUMENTS

Conductivity Equipment for Soil Testing—Bulletin A-12A (52)
Electrolytic Conductivity Equipment Catalog—4 pp. No. 24 (52)
Soil Moisture, Soil Salinity and Soil Fertilizer Testing Equipment Price List—(52)
Soil Sodium and Salinity Test Kit Circular—Form No. K600 (52)
Irrigating Scientifically—4 pp, Reprint (52)
Pasteurizer Flow-Timing Test Kit Bulletin—No. A-10 (52)
Moisture Meter Folder—(52)

(Continued on page 644)



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Directory of Suppliers

(Alphabetical list of firms whose literature is listed on pages 634 and 644)

1. **Acme Chain Corp.**, 821 Main St., Holyoke, Mass.
2. Aerovent Fan & Equipment, Inc., P.O. Box 9007, 5632 S. Pennsylvania Ave., Lansing 9, Mich.
3. **Aetna Ball & Roller Bearing Co.**, 4600 Schubert Ave., Chicago 39, Ill.
4. Aluminum Co. of America, 1501 Alcoa Bldg., Pittsburgh 19, Pa.
5. American Dryer & Equipment Co., 2720-60 Hillock Ave., Chicago 8, Ill.
6. American Iron & Steel Institute Committee on Galvanized Steel Sheet Research, 150 East 42nd St., New York 17, N. Y.
7. American Magnetics Co., P.O. Box 254, Moline, Ill.
8. **American Planter Co.**, Burr Oak, Mich.
9. American Steel & Wire, Div. United States Steel Corp., Rockefeller Bldg., Cleveland 13, Ohio
10. **American Zinc Institute**, 324 Ferry St., Lafayette, Ind.
11. W. R. Ames Co., 1001 Dempsey Rd., Milpitas, Calif.
12. **Armco Drainage & Metal Products, Inc.**, 703 Curtis St., Middletown, Ohio
13. Atlas Chain & Mfg. Co., P.O. Box 708, West Pittston, Pa.

13A. Bearings Company of America Division, Federal-Mogul-Bower Bearings, Inc., 501 Harrisburg Ave., Lancaster, Pa.

14. Babson Bros. Co., 2843 W. Nineteenth St., Chicago 23, Ill.
15. Badger Northland, Inc., Kaukauna, Wis.
16. Be-Ge Manufacturing Co., Gilroy, Calif.
17. Behlen Mfg. Co., Inc., Columbus, Nebr.
18. Big Dutchman, Automatic Poultry Feeder Co., Zeeland, Mich.
19. Bower Roller Bearing Div., Federal-Mogul-Bower Bearings, Inc., Detroit 14, Mich.

19A. Buckner Mfg. Inc., 1615 Blackstone Ave., Fresno, Calif.

20. Butler Manufacturing Co., 7473 E. 13th St., Kansas City 26, Mo.
21. **Chain Belt Company**, 4681 W. Greenfield Ave., Milwaukee 1, Wis.
22. Cleveland Graphite Bronze, Div., of Clevite Corp., 17000 St. Clair Ave., Cleveland 10, Ohio

22A. Continental Steel Corp., Kokomo, Ind.

23. **Daido Corp.**, 327 N. La Salle St., Chicago 4, Ill.
24. Dana Corporation, Toledo 1, Ohio
25. H. C. Davis Sons' Mfg. Co., Inc., Bonner Springs, Kans.
26. Dayton Industrial Products Co., Div. of Dayco Corp., Melrose Park, Ill.
27. De Bothezat Fans Div. of American Machine and Metals, Inc., East Moline, Ill.

27A. Delmar Publishers, Inc., Albany 5, N. Y.

28. The Deming Co., Salem, Ohio
29. **The Deniston Co.**, 4876 S. Western Ave., Chicago 9, Ill.
30. Detroit Diesel Engine Div., 13400 W. Outer Dr., Detroit 28, Mich.
31. Diamond Chain Co., Indianapolis 7, Ind.
32. Doane Agricultural Service, Inc., 5144 Delmar Blvd., St. Louis 8, Mo.
33. Dodge Mfg. Corp., Mishawaka, Ind.
34. Dukes Company, Inc., 3999 N. 25th Ave., Schiller Park, Ill.
35. **The Electric Wheel Co.**, Div. of Firestone Tire & Rubber Co., Quincy, Ill.
36. Erickson Products Co., 1960 Carroll Ave., San Francisco 24, Calif.
37. **The Fafnir Bearing Co.**, 37 Booth St., New Britain, Conn.
38. Farm Fans, Inc., 424 S. Pennsylvania St., Indianapolis 25, Ind.
39. **Federal-Mogul Div.**, Federal-Mogul-Bower Bearings, Inc.. 11081 Shoemaker, Detroit 13, Mich.
40. Fir Plywood Assn., 1119 A St., Tacoma 2, Wash.
41. Furnas Electric Co., Batavia, Ill.
42. Gering Plastics, Div. of Studebaker-Packard Corp., N. 7th St. & Monroe Ave., Kenilworth, N. J.
43. Gonset Div., 801 S. Main St., Burbank, Calif.
44. Hartzell Propeller Fan Co., Piqua, Ohio
45. Hastings Equity Grain Bin Mfg. Co., Hastings, Nebr.
46. Henke Mfg. Co., Columbus, Nebr.
47. Hercules Motors Corp., Canton, Ohio
48. **Huck Mfg. Co.**, 2480 Bellevue Ave., Detroit 7, Mich.
49. Hydreco Div. The New York Air Brake Co., Kalamazoo, Mich.
50. ILG Electric Ventilating Co., 2850 Pulaski Rd., Chicago 41, Ill.
51. Independent Nail & Packing Co., Bridgewater, Mass.
52. Industrial Instruments, Inc., 89 Commerce Rd., Cedar Grove, N. J.
53. Inland Steel Products Co., P.O. Box 393, Milwaukee 1, Wis.
54. **International Harvester**, 180 N. Michigan Ave., Chicago 1, Ill.
55. Byron Jackson Pumps, Inc., Box 2017, Terminal Annex, Los Angeles 54, Calif.

Names appearing in bold face type are advertisers in this issue. *(See page 634)*

56. James Mfg. Co., Fort Atkinson, Wis.
57. Kaiser Aluminum & Chemical Sales, Inc., 919 N. Michigan Ave., Chicago 11, Ill.
58. **Kohler Co.**, Kohler, Wis.
59. LML Engineering & Mfg. Corp., Columbia City, Ind.
60. Le-Hi Hose Accessories Co., Lehigh Ave. & 17th St., Philadelphia 32, Pa.
61. Lennox Industries, Inc., 1701 E. Euclid Ave., Des Moines 5, Iowa
62. Lesters Inc., Lester Prairie, Minn.
63. Libbey-Owens-Ford Glass Co., 811 Madison Ave., Toledo 3, Ohio
64. **Link-Belt Co.**, Prudential Plaza, Chicago 1, Ill.
65. **The Locke Steel Chain Co.**, 1230 Sabine St., Huntington, Ind.
66. The Louden Machinery Co., Fairfield, Iowa
67. Lovejoy Flexible Coupling Co., 4949 W. Lake St., Chicago 44, Ill.
68. Marietta Concrete Div., American Marietta Co., Marietta, Ohio
69. Marlow Pumps, Box 200, Midland Park, N. J.
70. Marsh Instrument Co., Skokie, Ill.
71. **Masonite Corporation**, 111 W. Washington St., Chicago 2, Ill.
72. Maurey Mfg. Corp., 2907-23 S. Wabash Ave., Chicago 16, Ill.

72A. Micro Switch, Div. Minneapolis-Honeywell Regulator Co., Freeport, Ill.

73. Mid-West Forging & Mfg. Co., 38 S. Dearborn St., Chicago 3, Ill.
74. Minneapolis-Honeywell Regulator Co., 2747 Fourth Ave. S., Minneapolis 8, Minn.
75. Morse Chain Co., Ithaca, N. Y.
76. Motor Wheel Corp., Lansing 3, Mich.
77. Mulconroy Company, 54th & Jefferson Sts., Philadelphia 31, Pa.
78. The Nagel-Chase Mfg. Co., 2811-23 N. Ashland Ave., Chicago 13, Ill.
79. National Electrical Manufacturers Assn., 115 E. 44th St., New York 17, N. Y.
80. **National Rain Bird Sales and Engineering Corp.**, P.O. Box 547, Azusa, Calif.
81. **National Seal Div.**, Federal-Mogul-Bower Bearings, Inc., Redwood City, Calif.
82. National Silo Assn., 131 Breckinridge Lane, Louisville 7, Ky.
83. Neapco Products, Inc., Pottstown, Pa.
84. **New Departure Div.**, General Motors Corp., Bristol, Conn.
85. New Holland Machine Co., New Holland, Pa.
86. Nice Ball Bearing Co., 30th and Hunting Park Ave., Philadelphia 40, Pa.
87. **Portland Cement Assn.**, Farm Bureau, 33 W. Grand Ave., Chicago, Ill.
88. **Raybestos-Manhattan, Inc.**, Passaic, N. J.
89. Republic Steel Corp., Republic Bldg., Cleveland 1, Ohio
90. Reynolds Metals Co., Reynolds Metals Bldg., Richmond 18, Va.
91. Rilco Laminated Products, W-891 First National Bank Bldg., St. Paul 1, Minn.
92. **Rockford Clutch Div.**, Borg-Warner Corp., 1325 18th Ave., Rockford, Ill.
93. Rockwell-Standard Corp., **Universal Joint Div.**, Allegan, Mich.
94. **Rollway Bearing Co.**, 541 Seymour St., Syracuse, N. Y.
95. The Ruberoid Co., 500 Fifth Ave., New York 36, N. Y.

95A. Scottdel Inc., Swanton, Ohio

96. Sealmaster Bearings, Div. of Stephens-Adamson Mfg. Co., Aurora, Ill.
97. A. O. Smith Corp., Harvestore Products Permaglas Div., Kankakee, Ill.
98. **Split Ballbearing Div. of MPB, Inc.**, Lebanon, N. H.
99. Starline, Inc., Harvard, Ill.
100. Stow Mfg. Co., 97 Shear St., Binghamton, N. Y.
101. **Stran-Steel Corp.**, Div. of National Steel Corp., Detroit 29, Mich.
102. Sturtevant Mill Co., Boston 22, Mass.
103. *Successful Farming*, Meredith Publishing Co., Des Moines 3, Iowa
104. **Texaco Inc.**, 135 East 42nd St., New York 17, N. Y.
105. **Timken Roller Bearing Co.**, 1835 Dueber Ave., S.W. Canton, Ohio
106. The Torrington Co., Field St., Torrington, Conn.
107. Triangle Mfg. Co., 740 Division St., Oshkosh, Wis.
108. Twin Disc Clutch Co., 1328 Racine St., Racine, Wis.
109. United Specialties Div., 9705 Cottage Grove Ave., Chicago 28, Ill.
110. U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
111. **U. S. Steel Corp.**, 525 William Penn Place, Pittsburgh 30, Pa.
112. Warner Automotive Div. Borg-Warner Corp., Auburn, Ind.
113. The Weatherhead Co., Fort Wayne, Ind.
114. **West Coast Lumbermen's Assn.**, 1410 S.W. Morrison St., Portland 5, Ore.
115. **Whitney Chain Co.**, Sub. of Foote Bros. Gear & Machine Co., 4579 S. Western Blvd., Chicago 9, Ill.
116. **Wisconsin Motor Corp.**, Dept. O-40, 1910 S. 53rd St., Milwaukee 46, Wis.

Manufacturers Explore Farm-Materials-Handling Theme

The widespread, brisk interest in the mechanization of farm materials handling prompted the Production and Marketing Department of the Farm Equipment Institute to select this subject as the central theme of its industry-wide meeting last May. Special emphasis, from the point of view of industry, was given to such aspects of the general subject as planning, evaluating, manufacturing and merchandising. As would be expected in this relatively new and rapidly expanding development, speakers at the meeting were quite in agreement on some aspects of it, but expressed widely divergent opinions on others.

In discussing the scope of the problem, an industry representative, using 1947-49 as a base period of 100, reported that grain production efficiency by 1957 had risen to 180, hay and forage-crop production to 125, production of milk cows to 120, but the production efficiency of meat animals had increased to only 108. In his view, further mechanization is the only means by which animal production efficiency can be brought up to a level with that of grain production.

The enormous quantities of materials that farmers are required to handle were put in startling perspective at this meeting when a USDA speaker stated that the American farmer handles more tons of hay than the country's steel industry produces in tons of steel. The following tonnage figures, in round numbers, are representative: Hay, 100 million; silage, 800 million; feed grains, 150 million; milk, 60 million; eggs, 350 million; fertilizer, 25 million. The enormity of this handling problem is further amplified by the fact that many of these products are handled more than once.

One company representative stated that the average farm uses 2,000 tons of water per year (exclusive of water for irrigation). Consumption (per day) of this water is as follows: 5 persons at 50 gal each (250 gal); 20 milk cows at 35 gal each (700 gal); 10 dry cows at 12 gal each (120 gal); 30 hogs and pigs at 4 gal each (120 gal), and cleanup and sanitation of dairy barn (100 gal). Total daily consumption, 1290 gal.

As might be expected, the type of retail dealer best qualified to merchandise materials-handling equipment was the subject of considerable discussion at this meeting. Three of the speakers were of the opinion that it should be the regular full-line implement dealer, but that a special department should be set up for the purpose. Three other speakers held opposite views, one of them stating that the specialized dealer is the one who is now doing the best job, though he thought the future might change the picture. Speakers favoring specialty dealers were of the opinion these dealers should do their own contracting work, including concrete construction, electrical installations, and similar work. These speakers also were of the opinion such a dealer would be entitled to more than the regular dealer discount, because of extra services performed for his customers.

Most of the speakers agreed that dealers should be paid on a consulting-fee basis for preparing sets of plans. One speaker stated that he charges $5.00 an hour for such service and that farmer customers are glad to pay it. Another speaker stated that a consulting fee could easily amount to 10 to 15 percent of the total cost of a materials-handling system, since it was similar to an architect's service fee in urban building construction.

It was further recommended that a dealer's materials-handling setup should be of the department-store type of retailing and be managed by a competent agricultural engineer, who should also supply such engineering plans as customers might require, as well as provide dependable service and repair parts. Stability in this area is a prime requisite, since some farmers have become discouraged on account of the turnover in dealers, also of manufacturers' changes in design, etc.

Two of the conference speakers put considerable stress on the desirability of dealers selling materials-handling equipment being also farm-management experts, since actually they needed to know as much or more about a farmer's operations than the farmer himself. It was pointed out that farmers cannot obtain all the service needed, and free of charge, from extension specialists or county agricultural agents.

It was also the consensus of the conference group that the engineering aspects of a selling program could be handled direct from the factory, or even from a few engineering centers throughout the country. One speaker, whose company had tried different setups to supply engineering information, said they had reached the conclusion that it should be supplied on a local basis. However, they did find that use of large, typical master plans supplied by the manufacturer greatly simplified the actual engineering work needed for each installation. All speakers were in agreement in recommending that more master plans and more complete machines be supplied by manufacturers to save making a custom job out of every switch and wire connection.

It was the unanimous opinion of all conference speakers that a complete materials-handling system be planned for any farm prior to making any machine sales. One speaker went so far as to say that a system of flow design should be set up first of all without regard to the existing buildings on a farm. With the flow pattern once established, it could then be altered more easily to conform to existing buildings than trying to work the system backwards. One speaker stated there have been some mistakes in planning systems because the designers thought all operations had to be designed for push-button operation. The fact of the matter is that some farmers have purchased more equipment than is justified by the size of their operations. It is desirable for farmers to consider systems that require some hand labor, or equipment that can also serve other farm uses.

Another speaker expressed concern as to the economic justification for materials-handlings systems. It was his thought that, if some farmers were oversold, the entire mechanization program would suffer setbacks. He advised the shifting of thinking from products to systems, and from the sale of a product to the economic justification for a mechanized installation.

Such systems have to be considered from the standpoint of all materials-handling problems, including the spreading of manure, hauling forages from field to storage and to feed lots, also moving such material from one storage to another. The point was made that it would be impossible to design a complete materials-handling system for a farm without designing a bulk system along with the integral system.

A USDA speaker expressed the opinion that a manufacturer should not attempt to perfect a piece of equipment without planning its integration into a complete materials-handling system. Otherwise it might be accepted as nothing more than a "gadget". All of the conference speakers appeared to be in agreement that, as more companies with larger manufacturing capacity engage in the production of a greater variety of materials handling equipment items, it will greatly simplify the problem for systems design engineers in selecting the various individual items of equipment that can be combined into a complete, efficient and economical handling system. All speakers stressed the great difference between designing various components for a materials-handling system and designing a plow or combine.

From the point of view of the best farmer customer for materials-handling equipment, it was stated he should be a USDA class 3 farmer or better, with at least a $5,000 annual cash farm income. He would need a minimum of 20 milk cows, or 40 head of beef cattle, or 200 head of hogs. The fact that dairy herds of 150 to 200 cows are becoming quite commonplace, with signs pointing to continued increase in the size of herds, adds further emphasis to the need of mechanized materials handling on farms. The greatest market area for equipment for such purpose appears to be among farmers with $250,000 of total invested capital, including land and invested capital.

Speakers at this FEI-sponsored conference agreed that the problem of servicing farm materials handling was different from that of servicing field machines only. Service and repair need to be available seven days a week, and from 4:30 a.m. to 8:30 p.m. The use of one-trip service trucks, carrying a supply of parts needed most often was specially recommended. Dealers not equipped to do electrical work will require the services of a competent electrician, on a seven-day-a-week basis to handle electrical problems.

The conference produced some significant predictions for the future. For example, it was predicted that self-positioning milkers would some day make the milking of cows completely automatic; even now in the development stage are milking units that will drop off the cow when the milk flow ceases. Cows will be let in and out of milking parlors by electronic means. It is even predicted that the future dairy will become a complete, straight-line processing operation with the final product being canned or packaged on the farm and in a form that will not require refrigeration.

During the past 150 years, almost all farm products have moved off the farm for final processing in factories. This trend might well be reversed, if and when farms are expanded and equipped to the point where they become actual farm factories.

One conference speaker stressed the point that, as people at large do less and less physical work, higher protein will be required. This will require greater production of protein foods. The tremendous bearing which an increase in the percentage of protein in the human diet may have on the further development and use of farm materials-handling equipment at once becomes apparent.

The FEI-sponsored conference brought out some significant prognostications on the market potential for materials-handling equipment. For example, there were 114,350 bulk milk tanks on farms a year ago last January. It is expected this number will increase to 225,000 by July 1965. A 20-million-dollar-a-year milking machine business is expected to increase to 60 million dollars a year by 1965. The 1960 sale of farm loaders is expected to approximate 40,000 units, and of manure spreaders,

(Continued on page 644)

It's interesting to design with concrete

Creative building designs reflect the imagination of the designer and the skillful use of structural materials. Materials available only in set sizes and shapes limit creativity. Concrete does not. Concrete members can be designed in many sizes and shapes to satisfy one specific requirement.

This is the third of a series of reports showing design techniques with concrete applied to specific parts of a building. The paragraphs and tables that follow show simple design methods for reinforced concrete beams. These methods are approximate but result in safe, economical designs.

Beams . . . a size and shape for every need

Beams of many shapes, such as rectangular, tee, I, box, double tee and channel are commonly used in construction. As shown in the example, the simplest of these, the rectangular and tee shapes, can be built in many different sizes that will carry a set load. It is readily apparent that the dimensions are strictly dependent on the needs and wishes of the designer. This freedom makes the design job interesting and permits real creativity.

Rectangular beams range from deep and narrow to wide and shallow. A deep beam requires less reinforcement and is usually the most economical. The beam depth should not be more than three times its width, and lateral support or bridging to prevent buckling is needed at intervals not greater than 32 times the beam width.

At the other extreme, the wide shallow beam is useful in locations of limited headroom. No limitations on width prevail; in fact, a reinforced concrete slab is designed as a series of wide flat beams.

Tee beams provide a wide compressive area with only a limited stem width in the tensile area. As may be seen by comparing Tables 1 and 2, a tee section will carry moments approximately equal to those carried by a rectangular beam of similar width and depth. However, the amount of concrete used in the tee section is considerably less than in the comparable rectangular section.

Most tee beams are a part of a concrete floor system where the slab and beam are built integrally. Under such conditions the maximum flange width "b" allowed in design is the least of the following:

(1) ¼ the span length of the beam,
or (2) 16 times the flange thickness "t" plus the stem width "b′,"
or (3) the center to center distance between parallel tee beams.

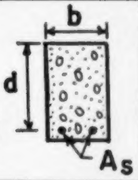
For isolated tee beams where the tee shape is used solely to provide additional compressive area, the maximum allowable flange width "b" is 4 times the stem width "b′." The flange thickness "t" shall be not less than one half the web thickness "b′."

Use of Tables 1 and 2

Tables 1 and 2 are useful to (1) design reinforced concrete beams and (2) determine the approximate moment capacity of beams of known size and reinforcement.

RECTANGULAR BEAM

TABLE 1



TEE BEAM

TABLE 2

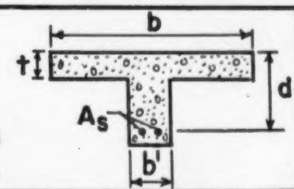


Table 1: $\frac{A_s}{bd}$	Table 1: $\frac{M}{bd^2}$	Table 2: $\frac{A_s}{bd}$	Table 2: Range of $\frac{t^*}{d}$	Table 2: $\frac{M}{bd^2}$
0.005	7.1	0.005	0.08 to 0.27	7.6
0.006	8.6	0.006	0.09 to 0.29	9.0
0.008	11.5	0.008	0.13 to 0.32	11.9
0.010	14.4	0.010	0.18 to 0.36	14.6
0.012	17.2	0.012	0.25 to 0.38	17.4
0.014	19.6	0.014	0.41 to 0.41	19.6

ASSUMPTIONS AND UNITS:

3,000 psi concrete (1,350 psi allowable compression).
20,000 psi allowable steel stress in tension.
b, d and t are in inches.
M is in foot pounds.
A_s is in square inches.

*The lower values of $\frac{t}{d}$ may be controlled by factors other than the load-carrying ability of the beam. (See discussion under Tee beams.)

Procedure for Design:

(1) Choose any $\frac{A_s}{bd}$ from Table 1 (or Table 2 for tee beams). The lower values will give smaller amounts of reinforcement and resulting deeper beams. The higher values approach a balanced design with concrete and steel both stressed near the design limit.

(2) Read the corresponding constant for $\frac{M}{bd^2}$.

(3) Solve for combinations of b and d. With these known, solve for A_s.

Design Example

Problem: Design a rectangular beam for a moment of 20,000 ft. lb.

(1) Choose $\frac{A_s}{bd}$. Say 0.005

(2) Therefore, $\frac{M}{bd^2} = 7.1$

$$\frac{20{,}000}{bd^2} = 7.1 \quad bd^2 = 2{,}820$$

(3) Set up table of combinations of $bd^2 = 2{,}820$

b	d	$A_s = 0.005\ bd$
8	18.7	0.75
10	16.8	0.84
12	15.4	0.92
24	10.8	1.30

Smaller beams with more reinforcement can be designed by starting with a larger value of $\frac{A_s}{bd^2}$. Tee beams with many different flange widths and thicknesses can be similarly determined from Table 2.

Cautions: (1) The dead load moment of the beam must be included in the total design moment. (2) Shear and bond stresses should be checked by methods described in ACI 318-56, "Building Code Requirements for Reinforced Concrete."

For more information on reinforced concrete design, write for free booklet, distributed only in the U.S. and Canada.

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Wallace Ashby


T. W. Edminster


William M. Bruce

Wallace Ashby, chief of the Livestock Engineering and Farm Structures Research Branch of USDA's Agricultural Research Service, recently retired after 38 years of government service. A native of Des Moines, Iowa, he received a B.S. degree in agricultural engineering from Iowa State University in 1913. His work on redevelopment of swamp and cut-over land in northern Minnesota was recognized in 1924 by the granting of the professional degree of agricultural engineer by ISU. From 1914 to 1917 he was employed by USDA as "barn architect"— the first person to serve in that capacity. With the exception of about 2½ years Mr. Ashby has remained continuously in charge of the department's overall program of research on farm buildings from crop storage and livestock shelters to housing for farm families.

A study in 1928 of clean plowing of land at Toledo, Ohio, to stop the spread of corn borers, by Mr. Ashby and his fellow workers resulted in a method of describing and evaluating plow bottom shapes to aid in the selection of plows with good covering ability. During World War II, as assistant director of the Hemp Division, Commodity Credit Corp., he helped direct a program for production of American hemp, to supplement scarce supplies of the fiber that had formerly come from the Philippine Islands. He attended the First International Congress of Farm Building Research at Lund, Sweden, in 1956, to discuss farm building problems, also visiting seven European countries to study their research and development work on farm buildings. He is also co-author of the text and reference book "Modern Farm Buildings," for persons in the farm building construction field.

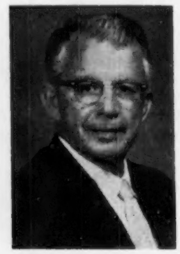
A member of ASAE since 1916, he was advanced to the status of Life Fellow in 1952 and in 1958, he was the recipient of the John Deere Medal.

Robert G. Yeck has been appointed chief of the Livestock Engineering and Farm structures Research Branch, Agricultural Research Service, USDA, to succeed Wallace Ashby who recently retired. Mr. Yeck came to the Department as an agricultural engineer in 1948 and has subsequently held positions of increasing responsibility in this field since that time. Most recently he was stationed at Columbia, Mo., as leader of environment control investigations.

T. W. Edminster has been appointed chief of the Eastern Soil and Water Management Research Branch, Soil and Water Conservation Research Division, ARS, USDA. He came to ARS in 1953 with the transfer of research from SCS and moved to Beltsville, Md., as an employee of the Division in 1954, in charge of drainage research throughout the eastern states. For the past year he has been serving as assistant chief of the Eastern Soil and Water Management Research Branch.

William M. Bruce has been appointed chief of the Harvesting and Farm Processing Research Branch of the USDA Agricultural Engineering Research Division at Beltsville, Md. He started with the department in the Soil Conservation Service in 1935. In 1948 he joined its Agricultural Engineering Division at Athens, Ga., transferring to the headquarters in Beltsville, Md., in 1952. He was appointed assistant chief of the Harvesting and Farm Processing Research Branch in 1957 and has been acting branch chief since May of this year.


Frank P. Hanson


Frank S. Foster

Frank S. Foster has recently been made manager of the sales division, defense products department, Caterpillar Tractor Co., Peoria, Ill. A Caterpillar employee since 1945, he has held a variety of assignments in the sales department, and since 1956 has been sales administrative assistant. During World War II, he was chief of the tracklaying tractor section of the War Production Board for 3 years.

Frank P. Hanson, ASAE Fellow and agricultural engineer for Caterpillar Tractor Co. since 1927, retired on July 1 from active business. A native of Iowa, he was born in Spaulding on August 14, 1897, and graduated from Creston, Iowa, High School. He received a B.S. degree in agricultural engineering in 1920 from Iowa State University. His association with ASAE began in 1920 when he became the first editor of the Journal, and subsequently assistant secretary, secretary, and treasurer. He also has served as vice-president of the Society and chairman of its Power and Machinery Division.

In 1922, he accepted the position of agricultural engineer with Portland Cement Association in Chicago, Ill. From 1922 to 1927, he was a staff member at the University of Illinois, as extension specialist in agricultural engineering. His affiliation with Caterpillar began in 1927 when he was appointed sales representative for one of its subsidiaries, Western Harvester Co. He subsequently held positions with its training bureau, and administrative department; was assistant manager and manager of the merchandise department; and agricultural engineer in the engineering department, which position he held until his retirement.

He is an active member of Farm Equipment Institute, having served as chairman of its Agricultural Research Committee, and as a member of its Advisory Council. In 1959, he received the Institute's merit award "for outstanding research and educational contributions to agriculture, industry, and the Institute." He holds memberships in Tau Beta Pi, Gamma Sigma Delta, Phi Kappa Phi, and Theta Delta Chi. He also is a

(Continued on page 646)

NECROLOGY

Keith H. Hinchcliff, professor of agricultural engineering, University of Illinois, was killed, along with his wife, Bethel, and younger daughter, Barbara, on July 24 when their car was struck by a passenger trian at a rural crossing near Kensington, Kans. Another daughter, Anne, survived but suffered shock and multiple lacerations. Professor Hinchcliff died in the town where he had attended grade school and high school. He was born October 12, 1911 in McFarland, Kans., and received a B.S. degree in architecture in 1933 from Kansas State University and an M.S. degree in 1934. From 1935 to 1937, he was a senior architectural draftsman with the National Park Service at Kaiser, Mo., where he designed recreational structures for the Lake of the Ozarks Recreation area. He taught courses in farm buildings, farm shop, and graphic methods as a University of Arkansas staff member from 1937 to 1941. He worked for the Mississippi State Extension Service, also as an expert in farm buildings until 1944 when he was appointed to the University of Illinois staff as an assistant professor of agricultural engineering in the agricultural extension service.


Keith H. Hinchcliff

In 1949 he became an associate professor of farm structures and in 1951 was appointed a full professor. During 1954 and 1955 he took a two-year foreign assignment as a self-help housing specialist to Indonesia under the Point IV Program. A publication based on his experiences in Indonesia, called "Leader Training for Self-Help Housing," was printed in 1957.

Other of Mr. Hinchcliff's publications include a major article on farmstead arrangement for the Encyclopedia Britannica and co-authorship of a book with D. G. Carter called "Family Housing." He also wrote a pamphlet entitled "Remodeling the Model T Farmhouse" for the University of Illinois.

He had been an ASAE member since 1941, and was also a member of Phi Kappa Phi, Sigma Tau, Gamma Sigma Delta, Epsilon Sigma Phi, and the American Society of Engineering Education.

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Pacific Northwest Section

The Pacific Northwest Section will hold its annual meeting October 19-22 at the Empress Hotel, Victoria, British Columbia, Canada. Registration will begin on Wednesday, October 19, at 6:00 p.m. followed by a program and social hour which will include a talk by T. L. Coulthard, chairman, agricultural engineering department, University of British Columbia, on an agricultural engineer's impressions of Spain, and the showing of the new ASAE film "Agricultural Engineering — The Profession with a Future."

A general program will open the meetings on Thursday morning with welcoming addresses by Newton P. Steacy, minister of agriculture, British Columbia, and P. B. Scurrah, mayor of Victoria. Also, the following topics will be discussed: "Business and Engineering in Agriculture"; "The Farmstead Must Grow Up"; "Materials, Men and Methods in Farmstead Operations"; and "Operations and Maintenance on a Modern Irrigation Project." Deputy Minister of Agriculture W. MacGillivray will speak at the noon luncheon, after which there will be a general tour by bus of specialty crops, flower bulbs, holly production, beef, and machinery. Thursday evening will be devoted to a student dinner, complimentary to students and faculty advisors of student ASAE branches, through the courtesy of R. M. Wade & Co., Portland, Ore., at which time student officers will be elected. Also on Thursday evening two concurrent programs will be held, the first one being a joint session of the Power and Machinery, Farm Structures, and Electric Power and Processing Divisions. Carrying through the theme "Building Design and Mechanization for the Farmstead," papers will be presented on power use on the farm; computer applications for farmstead mechanization; farm water and sewage development; and building considerations with farmstead mechanization. Election of division officers will conclude this program. The second concurrent session will be a Soil and Water Division program at which discussions will be presented on piping through dams and around spillways; progress on the watershed and flood protection projects in Washington; correlation of consumptive use of pasture with evaporation from several devices; correlation of consumptive use of crops with evaporimeters; and mathematical analysis of the border method of irrigation. Election of division officers will also conclude this program.

The first of two concurrent programs on Friday morning will be a joint Power and Machinery and Soil and Water Divisions session, at which the following topics will be discussed: "Sprinkler vs. Gravity Irrigation on the Sault Loch Project"; "No More Rock Jacks"; "Pasture-Development and Land Clearing"; "Irrigated Land Development-Progress and Requirements"; "Soil Improvement Studies on the Slick-spot Soils in the Lower Snake River Valley in Idaho and Oregon"; and "Site Preparation with the Holt Trencher." The second concurrent program will be a joint Farm Structures and Electric Power and Processing Divisions session, and will be devoted to papers on the present status and future needs of farm buildings; an experimental granary; how to fabricate and erect panelized farm buildings; survey of electrical equipment on British Columbia farms; electric load characteristics of farms; and hay pelleting. National ASAE President L. W. Hurlbut will speak on student recruitment of agricultural engineers at the Friday noon luncheon. The afternoon session will be of a general nature, consisting of Pacific Northwest Section student branches reports, presentation of student award papers, and the annual business meeting. The speaker at the annual banquet on Friday evening will be David B. Turner, deputy minister, recreation and conservation, Victoria, British Columbia.

On Saturday morning a tour of the Canada Department of Agriculture's agricultural experiment station at Saanichton, B. C., will be conducted. An interesting ladies' program is also planned for the three-day meeting period.

Ohio Section

The fall meeting of the Ohio Section will be held Friday afternoon, September 30, and Saturday morning, October 1, at Ives Hall, The Ohio State University, Columbus. The tentative program will include two concurrent programs on Friday afternoon. A separate program is planned for the Soil and Water Division. The other divisions will be combined in a program on materials handling. The Friday sessions will conclude with a 6:30 p.m. banquet. The Saturday morning session will be devoted to a student recruitment, the showing of the new ASAE film "Agricultural Engineering—The Profession with a Future," and the business meeting.

For those desiring to attend the Ohio State - Southern California football game on Saturday, October 1, a block of tickets has been reserved.

Chicago Section

The Chicago Section will hold its annual fall meeting and election of officers on September 26 at the Western Society of Engineers, 84 E. Randolph St., Chicago, Ill. This will be a dinner meeting with members of Chicago Farmers invited as special guests. The feature speaker of the evening, Walter Carleton, assistant director, Agricultural Engineering Division, ARS, USDA, Beltsville, Md., has selected as his topic, "Where To, From Here?" The program will also include a showing of the new ASAE film, "Agricultural Engineering — The Profession with a Future."

Michigan Section

At a meeting of the Executive Committee of the Michigan Section, the time and the place of the fall meeting was decided — October 29 is the date, and the place is Michigan State University. The meeting will consist of a morning technical meeting and ladies' program, luncheon, and the MSU-Ohio State football game in the afternoon.

Pennsylvania Section

The Pennsylvania Section will hold its fall meeting on Friday and Saturday, November 4 and 5, at Pennsylvania State University, University Park, Pa.

Minnesota Section

The following officers have been elected for the coming year, to serve the Minnesota section: A. M. Flikke, chairman; M. L. Gustafson, first vice-chairman; R. E. Larson, second vice-chairman; F. W. Kesler, third vice-chairman; W. A. Junnila, secretary-treasurer; and J. H. Pomroy, editor.

ASAE MEETINGS CALENDAR

September 26—Chicago Section, Western Society of Engineers, 84 E. Randolph St., Chicago, Ill.

September 30 - October 1 — Ohio Section, Ives Hall, The Ohio State University, Columbus, Ohio.

October 19-22 — Pacific Northwest Section, Empress Hotel, Victoria, B.C., Canada.

October 29—Michigan Section, Michigan State University, East Lansing, Mich.

November 4-5 — Pennsylvania Section, Pennsylvania State University, University Park, Pa.

December 5-7—Winter Meeting, Peabody Hotel, Memphis, Tenn.

April 7-8 — Mid-Central Section, St. Joseph, Mo.

April 14-15 — Southwest Section, Grim Hotel, Texarkana, Texas.

June 25-28—Annual Meeting, Iowa State University, Ames, Ia.

Note: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Mich.

Washington D.C. Section

The Washington D.C. Section held its first meeting of the season on Friday, September 9, in Room 6962, South Building, USDA, Washington, D.C. A. V. Krewatch, professor of agricultural engineering, University of Maryland, College Park, Md., spoke on materials handling, as well as demonstrating an improved technique of utilizing visual aids.

EVENTS CALENDAR

September 18-22 — Sixth *Pan American Federation of Engineering Societies (UPADI)*, Buenos Aires, Argentina, S. A. For further information contact Engineers Joint Council, 29 W. 39th St., New York 18, N. Y.

September 21-23 — *Prairie Farmer Farm Progress Show*, Donald Balty Farm, 7 miles west of Joliet, Ill. For information write to Show Manager, Maynard Bertsch, Prairie Farmer, 1230 W. Washington Blvd., Chicago, Ill.

September 21-23 — *Conference on Problems of Power Generation and Transmission*, Philadelphia, Pa. Write to The American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N. Y., for details.

September 21-23—7th annual *National Electric Farm Power Conference*, Kentucky Hotel, Louisville, Ky. For information write to: Inter-Industry Farm Electric Utilization Council, Inc., P.O. Box 577, Washington 4, D.C.

September 25-28—67th *Annual Convention, Farm Equipment Institute*, Statler Hilton Hotel, Dallas, Texas. Write to FEI, 608 S. Dearborn St., Chicago 5, Ill., for details.

September 26-29 — Fall Meeting of *The American Welding Society*, Penn-Sheraton Hotel, Pittsburgh, Pa. Contact AWS headquarters at 33 W. 39th St., New York 18, N.Y., for details.

October 5-7 — Tenth *Annual Meeting of Southern Farm Equipment Manufacturers*, New Gatlinburg Inn, Gatlinburg, Tenn. Write to SFEM, P.O. Box 9, Chamblee, Ga., for information.

October 9-15 — *Fire Prevention Week*.

October 10-14 — 15th annual *National Hardware Show*, Coliseum, New York, New York. Details may be obtained from Ted Black, Public Relations, Medical Arts Bldg., Reading, Pa.

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. . . Manufacturers' Literature

(Continued from page 634)

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Pipeline to Profit–24 pp (4)
ABC Sprinkler Systems–(11)
Rocker-Jet Sprinklers–No. 208-A (19A)
Agricultural Rainers–10 pp, 209-A (19A)
Irrigation Pumps–No. 1-57 (69)
Liquid Fertilizer for Pumps–No.LF-59 (69)
Full Circle Sprinklers–No. 60-A (80)

LOADERS

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Heavy-Duty Loaders and Backhoes–20 pp (54)

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Plastic Pipe Bulletin–12 pp, No. 994 (89)

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Polyethylene Film for Farm and Garden–No. GP-27 (42)
Polyethylene News–Informa Sheet No. 1 (42)
Polyethylene Plastic Greenhouses–News Bulletin No. 1 (42)
Uses of Polyethylene Film in Plant Propagation & Culture–News Bulletin No. 3 (42)
Plastic Covers for Trench Silos Pay Big Dividends in Miss. Tests–News Bulletin No. 5 (42)
Heating Systems for Polyethylene Plastic Greenhouses–News Bulletin No. 6 (42)

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Roller Bearing Literature–(19)
Bearing and Bushing Literature–(22)
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Turning Points to Better Farming: Ball Bearings and Ball Bearing Power Transmission Units–53 pp (37)
Ball Bearings–55 pp, No. 480-25M-6/59 (37)
Bearings, Bushings and Washers Literature–(39)
Ball and Roller Bearings–27 pp, No. 2550-C (64)
Heavy-Duty Conveyor Ball Bearing Literature–(84)
Ball Bearings Manual–41 pp, No. 190 (86)
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Cylindrical Roller Precision Thrust Bearings Catalog–28 pp, No. PT-659 (94)
Spherical Bearings and Rod Ends–15 pp, Bulletin 560 (96)
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Bearings Catalog–55 pp, No. 458 (106)
Heavy Duty Roller Bearings–No. 360 (106)
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V-Belt Drive Design and Selection Handbook–180 pp, No. 280B (26)
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Gear Boxes–Series WA 47-48-50-57 (112)
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Chain Catalog No. MSL (115)

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Screw Conveyors and Screw Feeders Booklet–76 pp, No. 2989 (64)
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Bunk Feeder Literature–(85)
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Shuttle-Stroke Poultry House Cleaner Bulletin –(56)
Automatic Trough Waterer Bulletin–(56)

Silo Unloaders:
Silo Unloader and Bunk Feeder Booklet–20 pp, No. 111 (15)
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Level-Cut Silo Unloader Booklet–20 pp, No. B-809-811 (66)
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Pump and Irrigation System Bulletin–No. BJP-57-73 (55)
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Submersible Pump Bulletin–12 pp, No. BJP-58-42 (55)

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Agricultural and Industrial Wheels Catalog–50 pp (76)

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Welded Wire Fabric Design Manual for Farm Use–28 pp, Form FC-40 (9)
Welded Wire Fabric Design Manual for Building Construction–44 pp, Form BC-50 (9)
Welded Wire Fabric for Concrete Reinforcement Catalog–178 pp, Form 6277B (9)

. . . Manufacturers Explore

(Continued from page 638)

60,000 units. It is predicted that the use of silos, silo unloaders and bulk feeders will continue to expand at a fast pace.

One of the conference speakers pointed to the corn picker-sheller as one of the best examples of the need for a complete system of operation before machines could be sold successfully. While the development of the picker-sheller many years ago made it possible for farmers to shell corn in the field, it was not until the corn crop drier was developed that the picker-sheller became acceptable to farmers. The use of the two machines together resulted in a system acceptable to the farmer.

The conference produced much evidence to recommend that farmers develop their farming systems so as to require more flexible units wherever possible, inasmuch as future development of equipment will result in more new items. Buildings and production systems should not be made so rigid that they cannot be changed at some future time.

. . . Capital Requirements of Engineered Farmsteads

(Continued from page 630)

(*d*) What will the farmer do with the time he saves? Will he increase the volume of business to pay for the improvement?

(*e*) What will be the annual upkeep and depreciation?

Mechanization requires a shift to higher investment and to a greater proportion of the cash operating costs on most farms. Decisions as to how much to spend for equipment, the kind of equipment to buy, and the desirable balance between fixed investments and annual operating costs are involved when the feeding operation is mechanized. The extent to which livestock farmers incorporate new developments and techniques into their operations depends on many factors, but may reflect largely the relative availability and cost of labor and capital. Each can be substituted for the other. Before decisions can be made as to which method may be the most economical, it is necessary to know the labor requirements, investment and annual cost of handling feed with different levels of mechanization.

The banker is often faced with the problem of how much credit is justified for this type of financing. The loan officer who, on the basis of a borrower's financial statement, attempts to answer this question by applying a simple formula or ratio is doomed to frustration. A policy based on the value of the collateral can readily be established in connection with equipment and livestock loans, but, if a farmer's entire operation is being financed, each credit request has to be considered in connection with the whole financial picture. Often the full purchase price of equipment or livestock will be advanced on the basis of margin in other collateral, anticipated profits, or merely because of their necessity to operations.

Generallv most corn belt rural bankers would prefer that the borrower's maximum total indebtedness not exceed his net worth, thus giving him at least a 50 percent equity in his business. However, I have often observed loans to tenant farmers which during peak periods have substantially exceeded this proportion.

The old, often-quoted textbook theory of restricting non-real estate farm credit to surplus current assets is no longer valid in an era of mechanization. The final test under that theorv was the question: "Can the farmer repav the loan and still have enough property left with which to continue farming?" This may have been a valid rule of thumb in the past when these assets consisted of horse-drawn machinery of nominal value, but it is not applicable today. How many present-day industrial or mercantile borrowers could liquidate their entire indebtedness and still continue operations? Any loan officer who restricts credit to such a limitation in 1960 cannot serve the complete credit needs of his customers.

In the final analvsis, the repayment of the debt will ordinarily be from future income which may or mav not bear some relation to the borrower's present finanical condition. The importance of the borrower's equity in his business should not be minimized, since it offers the lender protection against possible loss, but neither should it be the sole consideration in extending credit. The purpose of the loan and the ability of the borrower can often offset to a considerable extent some deficiency in capital.

Several months ago the author was asked to look at a loan request from an Iowa farmer. The Farm Clinic of West Lafayette, Ind., had been retained as consultant by the farmer to help reorganize his farm program. Here was a situation where the banker had looked only at a financial statement and as a result the farmer was in trouble.

The farmer had invested over $50,000 in a new livestock building and equipment. The program had been financed by short-term credit by bankers with no real concept of modern agriculture. As a result, when hog prices fell last year, the banks got worried and called their loans. At the risk of oversimplifying the problem, here was a situation where improper credit was given based on a financial statement. Had a budget been prepared it would have been clear that, even if everything went right, it would take three years to repay the loan.

If we are going to properly finance modern agriculture, and more especially the installation of engineered farmsteads, it is going to have to be done by the joint efforts of informed bankers, businesslike farmers and suppliers with service as well as materials to sell. The man who knows his product must help inform the banker and the farmer of its use and potential income-producing capacity.

. . . Members in the News

(Continued from page 640)

James H. Landers

Eugene C. Brown

member and past-chairman of the Agricultural Committee Association of Commerce; past-president and member of the District Elementary and High School Boards of Education; past-chairman of Peoria County Zoning Commission; and member and past-chairman of Peoria County Planning Commission. He reports that management of farm operations in Illinois and Iowa will serve to keep him busy for the immediate future.

James H. Landers, associated with the sales organization of Goodyear Aircraft Corp. since 1954, has been placed in charge of all commercial plastic sales. In his new assignment, he is responsible for sales of plastic products in all areas except the military. Prior to 1954, he was a member of The Goodyear Tire and Rubber Company's field sales organization for 11 years in the Texas area.

Eugene C. Brown has joined the staff of the Rockford, Ill., Works of the J. I. Case Co. as product engineer and division head in charge of the tillage machinery division. He is a graduate of A. & M. College of Texas and has been associated most recently with the G. A. Kelly Plow Co. of Longview, Texas, as a design and development engineer.

Elwood F. Olver has joined the agricultural engineering staff at the University of Illinois. He previously held the positions of director of the security department and associate professor of agricultural engineering at Pennsylvania State University.

Donnell R. Hunt, formerly assistant professor in the agricultural engineering department at Iowa State University, Ames, recently has joined the agricultural engineering staff at the University of Illinois, Urbana.

Kenneth E. Huddleston, who for seven years served as assistant executive secretary and director of public relations of the Farm Equipment Institute in Chicago, has been appointed executive secretary of the Forest Products Research Society. While with FEI he also served as director of the Pesticide and Application Equipment Manufacturers Association. He also served for nine years with the USDA and was with Ware Publishing Co. in Philadelphia as editor of the National County Agent and Vo-Ag Teacher and other publications.

Howard F. McColly

Howard F. McColly, professor of agricultural engineering, Michigan State University, East Lansing, will be leaving the country on October 1 for two years on an assignment to Formosa. He will be the group leader for the MSU project with National Taiwan University, involving a group of about five people from this institution.

E. W. Lehmann, past-president of ASAE and University of Illinois professor emeritus of agricultural engineering, has been named Southern Illinois University visiting professor of agricultural industries for the 1960-61 academic year. He will serve as a replacement in agricultural engineering for **Milton Shute,** who will be on sabbatical leave to work toward his doctorate at the University of Missouri. Mr. Lehmann was head of the agricultural engineering department at the University of Illinois until his retirement in 1955. Since retiring, he has served for three years as a special consultant to the International Harvester Co. and since 1958 as a consultant to the University of Illinois.

Henry Waelti advises that he is starting management training with Western Farmers Association in Davenport, Wash. He recently completed requirements for his M.S. degree in agricultural engineering at Purdue University, Lafayette, Ind.

Keith E. Robertson, who recently received an M.S. degree in agricultural engineering from Michigan State University, has joined the Kansas State University agricultural engineering staff as an instructor. His duties will include conducting research on projects sponsored by the Kansas Committee on the Relation of Electricity to Agriculture.

Tobi Goldoftas, formerly senior project engineer with J. I. Case Co., Fort Wayne, Ind., is now an associate editor with Hydraulics and Pneumatics magazine, a publication of Industrial Publishing Corp., Cleveland, Ohio.

Calvin K. Mutchler, agricultural engineer, Soil and Water Conservation Research Division, ARS, USDA, has been reassigned from St. Paul to Morris, Minn. In his new position in the runoff and control investigations, he will be conducting fundamental studies on the mechanics of rainfall.

Leonard Schiff, hydraulic engineer, Western Soil and Water Management Research Branch, SWCRD, ARS, USDA, Fresno, Calif., spent July 18 to September 2 in Europe. He attended the 12th General Assembly of the International Union of Geodesy and Geophysics in Helsinki, Finland, and his itinerary also included various points in England, Finland, Sweden, Netherlands, Switzerland, Italy and France, where he made a study tour of water recharge works.

Clifford L. Jenson, agricultural engineer, Western Soil and Water Management Research Branch, SWCRD, ARS, USDA, has been reassigned from Yuma to Tempe, Ariz. In 1956, he joined the Soil Conservation Service in Medford, Ore., and in 1957 was transferred to the Soil and Water Conservation Research Division in Brawley, Calif., and was reassigned to Yuma, Ariz., in 1958.

New Wafering Machine Shown to Agricultural Engineers

Production models of a new hay wafering machine were shown July 26 to agricultural engineers and farm publication editors, by the Lundell Manufacturing Co. at Cherokee, Iowa. This was said to be the world premier showing of a production model machine for wafering hay in the field.

Nominal dimensions of the wafers are 2 x 2 x 2 or 2 x 2 x 1 inch according to the operator's preference. Balanced weights of corresponding hay in baled and wafered form showed that the wafers had the same weight in about one-third of the volume.

Pre-wafering procedure involves cutting and windrowing, with a chopper and windrow attachment, which macerates, breaks and bruises a high proportion of the stems. This equipment also mixes the leaves and stems to a degree of uniformity in which they have been described as "homogenized."

The machine has been tested primarily on alfalfa and clover type hays, or mixtures containing at least 50 percent alfalfa or clover. Moistening equipment is built into the machine for use on hay which becomes field dried to a moisture content below that at which a suitably stable wafer is formed. Further drying of the wafered hay may be necessary or desirable in some cases.

Initial production of the machine is to be limited and made available to selected farmers considered qualified to pioneer its farm use.

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This post-and-lumber foundation was developed at the Illinois Agricultural Experiment Station. It's designed for speedy erection in any kind of weather.

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Pressure treatment of the lumber gives this foundation a long life —makes it resist farmstead acids and moisture. Pressure-treated West Coast lumber may be obtained through your retail lumber dealer.

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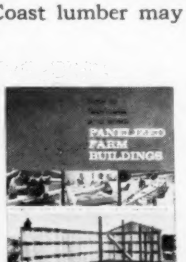

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. . . Costs and Benefits of Engineered Farmsteads

(Continued from page 627)

tems, then labor may be left out of the analysis. Following are the items required to carry out a partial budget:

1. Added costs
2. Reduced returns
3. Total added costs and reduced returns (sum of items 1 and 2)
4. Added returns
5. Reduced costs
6. Total added returns and reduced costs (sum of items 4 and 5)
7. Balance of costs and returns (subtract item 3 from item 6).

Computation of the partial budget requires that all extra costs of the change to be evaluated, for instance the cost of adding a mechanical feeder, be recorded under item 1, "added costs." Even feed and related costs resulting from an expanded business are placed in this category. The enterprise or business with which the mechanical feeder is to be used, is then scrutinized for any possible reduction in returns that might result from the use of the additional equipment and, if applicable, expanded volume of business. These reductions in returns are itemized in category 2 and the total negative effect is summed (item 3).

All added returns, such as increased milk sales from a larger dairy herd, or an increase in product price due to storage of grain for most opportune sale, are brought together under item 4. Reduced costs are recorded under item 5. They include the reduction in equipment costs associated with the method being replaced plus any other savings that the new equipment, building, or system will make possible, such as less feed per unit of product.

The added returns and reduced costs, as totaled in item 6, represent the gross advantage of the factor or factors under consideration. The net advantage or disadvantage of the addition to or change in equipment or buildings is found by subtracting the total added costs and reduced returns (item 3) from the total added returns and reduced costs (item 6).

LOOKING AHEAD

As a factor of production, a farmstead unit should be designed to retain a high degree of usefulness through time. Buildings are expected to decline in value as a result of wear and tear and decay. The rate of this physical depreciation can be predicted with considerable accuracy. Reduction in value also occurs as a result of facilities failing to meet changing needs.

Those responsible for developing buildings, equipment, and other features that make up a farmstead have always been faced with the certainty that there would be some growth in technology and that the best they had to offer today would be obsolete before expiration of physical life. If technology continues to grow at the rapid pace set in recent years, then past difficulties arising from obsolete facilities and farmstead units may well seem small. The basic character of agriculture, particularly animal agriculture, may be on the verge of some drastic changes. Since the farmstead unit is inseparable from the farm business unit, it must be considered in the light of factors that will affect the business. If designers of the components and the planners of farmstead systems expect the results of their efforts to remain economic components of agriculture 10, 20, or 40 years from now, then they must appraise the probable character of future agricultural developments most carefully.

Perhaps livestock production will combine the technological developments in nutrition, disease control, mechanization, and other internal factors of production with the external economies that may be possible in large-scale production, and will move into large centralized units of an industrial nature. On the other hand, perhaps livestock production will absorb the advancements in production techniques yet remain farm oriented. An evaluation of these possible adjustments is not within the scope of this paper, but farmstead planners must either accurately forecast the direction and extent of such adjustments or, if they cannot do so, they must design with flexibility and a high rate of capital turnover as key ingredients.

. . . Electric Power Supply

(Continued from page 632)

improved methods of farming. Some electric power suppliers have already assumed their responsibility for providing assistance, advice and counsel to farmers as to ways that electricity can help them in mechanizing and improving their farmstead operations. I do not feel qualified to judge the quantity and quality of the assistance given by manufacturing, research and education groups, but I feel that every power supplier serving the rural market can, and should, develop a much improved and dynamic assistance program for farmers to help them in the transition to fully electrifying their farmstead operations. Power suppliers can well afford to maintain a staff of agricultural engineers and other power-use personnel who are aware of the new developments and improved techniques which can be of value to the type of agriculture being carried on in their service area.

This whole area of improving the position of agriculture presents a challenge to each of us for the future. It is my belief that electricity and its application to agriculture will play a key role in the future success of the farmer. We have seen that the potential exists, and it is up to us—the research and education people, the manufacturers and distributors of farm equipment, and the power suppliers of rural America — to meet this challenge.

May I urge agricultural engineers from their respective positions of influence to:

1 Encourage power suppliers to pursue service policies relative to the availability of power and to maintain rates that will encourage the maximum use of electric power on the farm.

2 Encourage power suppliers to plan well so that they can provide the maximum amount of agriculture's future power requirements at a low cost.

3 Work to achieve continuing coordination and cooperation between research, education, manufacturing, and power suppliers. This will include keeping each group informed of developments in all of these fields.

4 Encourage increased activity by all groups, including power suppliers, that will provide the advice and assistance to farmers needed to enable them to better apply electricity to their agricultural operations and to provide the increased emphasis that needs to be placed on the farm production uses of electricity.

Soil Compaction Bibliography

An Annotated Bibliography on Soil Compaction consisting of over 600 references with a short description of each reference and complete with subject index has been published by the American Society of Agricultural Engineers. The publication is a contribution of the Bibliography Subcommittee of the Soil Compaction Committee of ASAE, with representation from the Soil Science Society of America. Copies are available at $1.50 each ($1.00 to ASAE members). Quantity price for 25 copies or more is $1.00 each. Orders with remittance may be sent to ASAE, 420 Main St., St. Joseph, Mich.

. . . Future Farmstead Power Requirements

(Continued from page 631)

eral, this category will cover tractors, trucks, and self-propelled and field portable machines. Since an operator is required, the purpose of the machine is to increase his productivity. Therefore, the first concern should be with his safety and comfort, and then with the capabilities of the machine.

The power requirements of each of this group of machines is affected by the requirement of operator safety and comfort, as well as machine capabilities, since energy is required to operate power accessories. In the design and development of some of these machines, it appears that operator safety and comfort were incidental, when provided at all. To illustrate the point, the present-day utility or tricycle-type farm tractor can be used. Its general form is that of the 1890 steamers, but it has an internal-combustion engine, rubber tires, three-point hitch optional, and power steering also optional. The astride position of the operator and the unhandy access to the seat are hazardous, since there is no ladder, and the power take-off shaft, the fenders, and the seat itself block access. The brakes are the two-wheel type, and usually ineffective and inconvenient to secure in a locked position. The machine has poor stability, but the operator is offered no optional rollbar and safety belt. The addition of a cab for protection from sun and rain increases the hazard for the operator. Developed as a plow horse, with a power take-off stub shaft added, it still offers few concessions to those who would ask it to do other jobs than to pull a plow.

If we keep this traditional machine in service for economic reasons, then a few options by manufacturers might be made available for those tractors which do not find their way to the hitch point of a plow. One of the least difficult would seem to be general availability of the reverse-drive cotton picker modification usable for loaders and other mounted machines. Certainly the general use of the front-end loader does not imply that the farm operator who has use for a loader would not use something else, if there was a choice at less than triple the initial cost. It is also indicated that the field chopper at least, among the list of machines now towed, would have improved capabilities if provided with a self-propelled mount.

In addition to the plow horse, in the days of animal power in American agriculture, there was a more versatile animal, the Morgan. This was a road horse as well as a draft animal. He had high performance and low weight per horsepower. As a traction machine his performance was increased with a man on his shoulders to keep his front feet on the ground. He was an effective four-wheel-drive machine, and it will be noted that for extreme traction conditions, the weight was added to the front end and was easily removable.

The Morgan's counterpart for today's farmstead and field power requirements is non-existent in national distribution. This machine would be light-weight, high-performance, four-wheel drive, with good floatation and traction, for a moderate cost, and requiring modest maintenance with excellent road and light field capabilities, and moderate abilities for emergency heavy-draft requirements. The jeep almost makes it, but it is the counterpart of the 850-lb pony. So we have Percherons and the Belgians, but no Morgans.

As a result, it seems that innovators have gone in all directions at once seeking an answer. The horsepower race in tractors sought to pick up the load of power accessories and to help to provide versatility. That effort did accomplish these two items, plus more power, more engine speed, more road speed, and an educational program on safety — but not too much functionally with stability, brakes, and operator comfort and safety. The farmer who thought about economy, and then safety, found his solution for transport by obtaining used trucks. Custom-built and other self-propelled machinery appeared on farms whose size of business could carry the investment. One of the most notable accomplishments of this dispersion of effort was the increase in operating costs to the dealer and the farmer due to spare part and service requirements.

In all this burst of effort, the manufacturer seems to be between the devil of the varied requirements of the few million units in the agricultural industry, plus a few other problems, and the deep blue sea of trying to operate at a profit. He is trying to supply components for systems, developed at each farm from individual experience and requirements, and usually these components are bought on price, or color of paint, and not necessarily on performance specifications.

Furthermore, the systems and their components are in a state of rapid change due to the impact of other innovations and of scientific discoveries. While the power requirement of the internal-combustion-engine-driven group of machines is mostly in the 2 to 125-hp range, the trend seems to be pointed up by the new 1000-rpm power-takeoff standard. The experience with self-propelled machines of all types also indicates that part of the improvement to the initial innovation is to increase engine power in 10 to 25-hp increments to provide good capacity and better operating characteristics generally. This points the direction for the pelleting or wafering machine in the direction of about 200 hp, by the time this machine attains workable form and field acceptance, barring a breakthrough which develops a very high mechanical efficiency for the process.

If and when total mechanization of forage harvesting is finally achieved through a combine, this unit will dwarf some of the present power requirements. Some of the components indicated as required for this machine are not yet developed. The pelleting machine seems to be in process, and the cutterbar assembly could come from the large self-propelled field chopper. The dewatering press and the dehydrator are not available in forms which could be set into this field harvesting machine. With field capacity in any reasonable amount, this machine will have a high power requirement in the presses, and the deyhdrator will need a a large supply of thermal energy. A gas turbine of 800 to 1,000 hp would seem to be capable of providing the exhaust heat for the dehydrator, the power for the presses, header, and conveying equipment, and for propelling the machine. The unit cost per ton of dehydrated forage is indicated to be a satisfactory figure, if this machine could harvest 8,000 tons annually, and the initial cost were under $75,000.

This last example makes the point most easily, that availability of power and the power requirement are ready and able when and if the utilizing means is provided. The extent and degree of innovation which can be brought to bear to utilize power is the controlling factor. As progress in this area is made, there is further improvement in the productivity of labor, and in quality and availability of product through more economical systems of energy conversion.

Summary

Future farmstead power requirements, whatever the "engine" and its "fuel," can be expected to increase as research, innovation, and design find ways to improve the productivity of labor through the utilization of mechanical and electrical energy. With both mechanical and electrical equipment, more attention is due the demand-use, or load factor, to assist in controlling the cost of using this equipment. Options in equipment offerings, to improve versatility and to decrease costs from manufacturer to user, appear to be an alternative to custom and specialized machines of local and farm shop manufacture, for some operations. In any innovation, safety and operator comfort are functional, just as is any other production capability of the machine.

RESEARCH NOTES

Brief news notes and reports on research activities of special agricultural-engineering interest are invited for publication under this heading. These may include announcements of new projects, concise progress reports giving new and timely data, etc. Address: Editor, AGRICULTURAL ENGINEERING, St. Joseph, Michigan.

Bulk Milk Tank Research Discussed

Plans for studies of the effect of bulk tank performance on milk quality were explained recently to 20 representatives of 12 tank manufacturers at USDA's Agricultural Research Center, Beltsville, Md.

The visitors inspected three new bulk tank installations to be used in the experiments. Milk will come from the USDA dairy herd at Beltsville. Agricultural engineer D. R. Mackay and dairy specialist R. D. Plowman, both of USDA's Agricultural Research Service, discussed the research plans. Types of tanks to be used are direct expansion, direct expansion under vacuum, and ice bank.

A reported 140,000 bulk tanks were being used in the U. S., as of last January 1. This is more than 4 times the number reported 4 years ago. Indications are that 300,000 tanks may eventually be used.

List of Reports on Tillage and Traction Research

A list of publications on tillage and traction research, conducted at the National Tillage Machinery Research Laboratory since it opened in 1935, is available from USDA.

Early publications listed include reports on studies conducted by agricultural engineers of the Alabama Agricultural Experiment Station before the laboratory was established in Auburn.

The list may be obtained from ARS Information Division, USDA, Washington 25, D. C. Request ARS-42-40, March 1960, "Publications List on Tillage and Traction."

Report on Mechanical Harvesting of Red Cherries

A research report on mechanical harvesting of red tart cherries has been reprinted for distribution by the Michigan Agricultural Experiment Station. The report, now in bulletin form, first appeared in Michigan's *Quarterly Bulletin,* Volume 42, No. 4, May 1960.

The report discusses how favorable results were obtained in extensive studies of separating, collecting, and handling equipment. Cooperating in the research were J. H. Levin and S. L. Hedden, agricultural engineers of AERD, ARS, USDA; horticulturist H. P. Gaston of the Michigan station, and USDA biochemist R. T. Whittenberger.

For copies of the report, write the Michigan station at East Lansing, mention Article 42-60, "Mechanizing the Harvest of Red Tart Cherries."

Report on Weeding Research

Reprints of "Weed Control Practices, Labor Requirements and Costs in Cotton Production" are available.

The research report, a reprint from *Weeds,* Volume 8, No. 2, April 1960, discusses evaluation of 16 weed-control practices. These involve use of combinations of hand hoeing, a pre-emergence herbicide, post-emergence oil, and flame in hill-dropped and cross-cultivated cotton.

The experiments were conducted at Stoneville, Miss., by agronomist J. T. Holstun, Jr., agricultural engineer O. B. Wooten, Jr., plant physiologist C. G. McWhorter, and agricultural economist G. B. Crowe, all of ARS.

Copies of the reprints are available from Harvesting and Farm Processing Research Branch, Room 326 North Building, USDA Plant Industry Station, Beltsville, Md.

Moore Heading USDA Ginning Lab

Vernon P. Moore of the National Cotton Council, Memphis, Tenn., is now directing USDA's Cotton Ginning Laboratory at Stoneville, Miss.

He succeeds Charles M. Merkel, who resigned to become vice-president in charge of engineering research with the Continental Gin Company.

Moore was closely associated with research on maintenance and evaluation of cotton quality during several years with USDA at the Stoneville laboratory. As staff technologist of the Cotton Council at Memphis since 1956, he has continued the direction of research along similar lines in working with all segments of the industry concerned with cotton quality. He is author and co-author of a number of publications dealing with cotton quality evaluation.

New Regional Publication on Cotton

A new regional publication, 71st in a series, on controlling weeds in cotton and mechanized cotton production is available at each of 12 State Agricultural Experiment Stations.

The publication is comprehensive in that it offers information, based on research, applicable in the four major cotton producing areas — the Southeast, Mid-South, Southwest, and Far West.

Discussed are land preparation, planting, selection and use of herbicides, herbicide application, mechanical weed control, flame cultivation, sprayer calibration, and sprayer operation and maintenance.

Cooperating were the Agricultural Experiment Stations of Alabama, Arizona, Arkansas, California, Georgia, Louisiana, Mississippi, New Mexico, North Carolina, Oklahoma, South Carolina, Texas, and AERD, ARS, USDA.

When writing for the publication, request "Weed Control Equipment and Methods for Mechanized Cotton Production," Southern Series, Bulletin No. 71, April 1960.

Report on Pressure Plate Adjustments

A reprint of a report on how pressure plate adjustments effect cotton picker performance is being distributed. The report was prepared by agricultural engineers L. M. Carter of AERD, ARS, USDA, and J. R. Tavernetti of the California Agricultural Experiment Station.

The report indicates that the optimum setting of pressure plates depends on the amount of green bolls on plants. When there are few green bolls, the plates should be set with a high yield pressure and close spindle clearance to obtain greatest picking efficiency. If there are many green bolls, a light to medium pressure and a one-fourth inch to one-half inch spindle clearance give best results. This reduces picking efficiency, but that is offset by the loss of fewer green bolls.

Copies of the reprint will be sent on request. Write Harvesting and Farm Processing Research Branch, AERD, ARS, Room 326, North Building, USDA Plant Industry Station, Beltsville, Md.

Report Discusses Heat Pump for Rural Homes

Electrical characteristics of an air-to-air heat pump for heating and cooling small

rural houses is the subject of a recently printed report of USDA.

The report, in summary, suggests that use of the heat pump provides better winter-summer balance in consumption of electric power. This can result in convenient, economical, and automatic year-round comfort air conditioning.

Authors of the report are agricultural engineers C. P. Davis and L. E. Campbell of AERD, ARS, USDA. The work was conducted at the Agricultural Research Center, Beltsville, Md. Aiding were AERD agricultural engineers G. R. Mowry, J. G. Hartsock, A. A. Biggs, and H. J. Thompson.

To obtain the report, write Information Division, ARS, USDA, Washington 25, D. C. Ask for ARS 42-41, "Report on Electrical Characteristics of an Air-Source Heat Pump," May 1960.

Fertilizing for More Early Tomatoes

Yields of early tomatoes go up ¼ to 1½ tons an acre if fertilizer is placed 1½ to 2 inches directly below seedlings in the field, USDA agricultural engineers are finding in preliminary studies.

Headed by W. C. Hulburt, the researchers of AERD, ARS are working at Beltsville, Md., in cooperation with a major vegetable processor. They point out that net returns to growers for early harvests are often many times greater than during the peak of the picking season.

Additional information on this research *will not* be available until studies are completed this season.

Building Plans Reviewed

Farm housing and service building plans were reviewed for selection, revision, or rejection at a recent (July 25-29) meeting of the Western Regional Plan Exchange Committee at Corvallis, Oreg. This committee of the Cooperative Farm Building Plan Exchange also considered work for the coming year.

Norman C. Teter, investigations leader of the Exchange, Willis F. Edgerley, Archie A. Biggs, and Russell E. Parker, architects, attended the meeting as representatives of AERD in USDA's ARS. (Mr. Parker is employed jointly by the Department's Institute of Home Economics and AERD.)

A representative of the Farmers Home Administration also attended the meeting. FHA considers the Plan Exchange of great value, since more than 50 percent of prospective borrowers do not present adequate building plans. Most FHA field supervisors are agriculturists, not building specialists, and need more good plans and leaflets.

The committee consists of representatives of 11 Western State agricultural colleges, AERD, IHE, and the Federal Extension Service.

Dudley Transfers to Bushland

Richard F. Dudley, Jr., research engineer of AERD, ARS, USDA, has transferred from Beltsville, Md., to the Southern Great Plains Research Station, Bushland, Tex.

He is developing improved planting and fertilizing equipment and methods for the Great Plains.

Before joining AERD in 1956, Mr. Dudley was on the staff of the Mississippi Agricultural Experiment Station.

New Building at Tillage Laboratory

USDA's National Tillage Machinery Laboratory, Auburn, Ala., will be expanded by a new building, authorized by Congress in the 1961 appropriation for the Department.

The $400,000 structure will provide increased laboratory space for fundamental studies, offices, and storage areas for soil bin equipment.

NEW FILM RELEASES

Water Bill U.S.A. 27 min. Color and sound. Water and what we must do to assure a plentiful supply for the future is the basis for this film. Narrated by Walter Cronkite, it illustrates the problem and tells how citizens in various parts of the country have solved their problem and what others can do about theirs. Available from Caterpillar Tractor Co., Peoria, Ill.

Hay-in-a-Day, the One-Man Way. 16mm. 10 min. Color and sound. This film shows how a farmer, using a team of machines, can now do the haying job from start to finish all by himself. It depicts the entire system step by step, emphasizing the three improvements which make it possible — mechanical loading of short bales in the field, drying them on the wagon, and moving bales into storage with a new kind of elevator-conveyor system designed for use by one man. The film was produced by New Holland Machine Co. in cooperation with Pennsylvania State University and is available on a free-loan basis for showing to agricultural groups from New Holland Machine Co., Box 7, New Holland, Pa.

. . . Beef — Livestock-Production Plant of Future

(Continued from page 621)

Trends and new developments in livestock production will bring about further changes or accelerate the adoption of advanced techniques. Some new ideas have been projected in the light of these new developments. Automation will find wide applications, including recording and analyzing productivity data, and in a variety of handling and processing operations. The extent to which automation can be applied will determine to a large extent the size of operation which one man with or without a helper can take care of effectively.

The handling of manure through slatted-floor systems for large animals combined with continual mechanical removal offers some hope of solving a bottleneck not only in labor but also in bedding with its storage and handling. These together with other such developments as automatic milking and candling, processing, and packaging of eggs, if found to be practical, would contribute greatly to advancement in the livestock industry.

References

1 Kock, W. E. *et al.* Application of automatic control techniques to future agricultural machinery. 28-page multilith. Bendix Aviation Corp., Research Laboratories Div., Detroit, Mich. November 1959.

2 Furry, R. B. The pentairy. 4 page multilith. New York State College of Agriculture, Cornell. Agr. Engr., New York. March 1960.

3 Merrill A. L. and Watt, B. K. Energy value of foods. U. S. Department of Agriculture Handbook No. 74, March 1955.

4 Committee on animal nutrition. Nutrient requirements for domestic animals. Reports 1 to 4, Agricultural Board of the National Research Council, 1954-1959.

5 Strohm, John. Farmer with a message and a method. *Reader's Digest.* 76. No. 458, pp. 148-152, June 1960.

6 Anonymous. The Ross-Holm milking method. *Redwood Rancher,* April 1958.

7 Herrmann, M. W. The milking equipment revolution. Talk presented at the spring meeting of the Production and Marketing Dept., Farm Equipment Institute, Congress Hotel, Chicago, Illinois, May 24, 1960.

8 Buckler, Peter. Slatted floors. The Farm Buildings Assn. journal (England), pp. 38-43, December 1959.

PERSONNEL SERVICE BULLETIN

Note: In this bulletin the following listings current and previously reported are not repeated in detail. For further information, see the issue of AGRICULTURAL ENGINEERING indicated. "Agricultural Engineer" as used in these listings is not intended to imply any specific level of proficiency or registration as a professional engineer. Items published herein are summaries of mimeographed listings carried in the Personnel Service, copies of which will be furnished on request. To be listed in this bulletin, request form for Personnel Service listing.

Positions Open—March—O-57-608, 66-609, 83-610. **April**—O-105-612, 111-613, 114-614, 126-617. **May**—O-169-618, 171-619, 187-620. **June**—O-231-621. **July**—O-237-622, 245-623, 256-624. **August**—O-270-625.

Positions Wanted — March — W-46-11, 63-13, 62-14, 69-16, 73-18, 74-19, 76-20, 94-21. **April**—W-99-24, 102-25, 96-26, 110-27, 127-28, 12-29, 117-31, 120-32, 121-33. **May** — W-101-34, 140-35, 129-36, 156-38, 175-39, 119-40, 158-41, 103-44. **June**—W-190-45, 207-47, 208-48, 199-49, 193-50. **July**—W-221-53, 238-54, 247-55, 252-57, 253-58, 254-59, 257-60. **August**—W-263-61, 264-62, 265-63, 262-64.

NEW POSITIONS OPEN

Agricultural Engineer for extension work, primarily in farm structures and materials handling, in an eastern state. MSAE or PhD preferred. Experience in field desirable. Usual personal qualifications for extension work. Normal opportunity for advancement. Opportunity for combination of extension and teaching or research if desired. Salary open. O-271-626

Agricultural Engineer for extension work in Soil and Water phase of agricultural engineering. Work in irrigation, soil and water conservation and water conservancy districts. Location in North Central state with large agricultural engineering department at land grant institution. MS degree in agricultural engineering (Soil and Water), with some experience necessary. New facilities and agricultural engineering building. Salary and rank open. Open August 1, 1960. O-303-627

Agricultural Engineer, climatologist in agricultural engineering department, North Central land grant institution. Weather data and microclimatology in conjunction with meteorology and soil physics work. Weather instruments and technician help available. Teaching and research program established. PhD desired, MS with experience considered. Excellent facilities. Salary and rank open. Open immediately. O-303-628

Agricultural Engineer to be in charge of power and machinery section (teaching and research) with North Central agricultural engineering department, land grant college. PhD in agricultural engineering desired, with MS and additional work and experience to be considered. Teaching and research experience in power and machinery necessary. Large undergraduate enrollment and graduate program in power and machinery at present time. The finest facilities and equipment for all phases of work. Salary and rank open. Open September 1, 1960. O-303-629

Agricultural Engineer, teaching and research in irrigation and drainage field with emphasis on hydraulic research. Located in North Central States area. Agricultural engineering department at a land grant institution. Excellent facilities in new building and completely new hydraulics laboratory with new equipment. MS degree in agricultural engineering (Soil and Water) with some experience necessary. Salary and rank open. Position open October 1, 1960. O-303-630

Senior Designers (several) for work on farm structures, with particular emphasis on stress analysis, and machine design with emphasis on gear, rotating machinery and materials handling equipment design. Established manufacturer. Location in midwestern city of 30,000 population. Age under 50. BSAE, BSME, or BSCE. Responsible drafting experience 5 to 8 years. Opportunity for advancement depending on ability. Salary open. O-273-631

Design Mechanical Engineer, for new products, modifications, and related field testing with eastern manufacturer of small power equipment. Age, up to 45. BSAE or BSME. Experience in gear box design and metal fabrication desirable. Recent graduate considered. Prefer married, sober man interested in permanent home in the area. Excellent opportunity in expanding engineering department with additional product development program. Salary open. O-284-632

Graduate Assistantships (3) in research with agricultural engineering department in an eastern state university. BSAE, or equivalent, with academic average of at least 2.5 for junior and senior years. Openings effective Sept. 15, Feb. 1, 1961, or July 1, 1961. Eleven months duty, one month vacation. Salary $3,024 plus tuition. O-306-633

Project Engineers (2) for design and development work on corn and forage harvesting equipment with medium-sized manufacturer well established in the farm equipment field. Midwest location. Age 25-35. BSAE or BSME. Three to ten years in farm equipment engineering. Able to assume responsibility for design and development for production of major components or completed units of farm equipment. Farm background preferred. Excellent opportunity for advancement. Salary open. O-309-634

Junior Engineer for variety of beginning engineering duties, including drawing, field testing, and experimental shop fabrication of parts, with medium-sized manufacturer in farm equipment field. Midwest location. Age 22-30. BSAE or BSME. Farm background preferred. Will consider trainee. Excellent opportunity for advancement. Salary open. O-309-635

NEW POSITIONS WANTED

Agricultural Engineer for design, development or research in power and machinery with college, experiment station, or manufacturer. Any location. Some preference for South. Married. Age 23. No disability. BSAE, January 1960, University of Southwestern Louisiana. MSAE expected January 1961, A & M College of Texas. Farm background. Research assistant while working on MS degree. Available February 1961. Salary open. W-274-65

Agricultural Engineer for extension, sales, service or management in power and machinery, farm structures, or rural electric field with college, manufacturer, processor or distributor in north central area. Widower. Age 42. No disability. BSA with major in agricultural engineering, 1941, Michigan State University. Experience as farm operator and assistant to drainage contractor. Available November 1. Salary open. W-281-66

Agricultural Engineer for design, development, research, sales, or writing, any branch of agricultural engineering, industry or public service, preferably in Southeast. Willing to travel. Married. Age 27. No disability. BSAE, 1955, Clemson Agricultural College. Short period of engineering work with large aircraft manufacturer. Military experience in photography, maintenance of aircraft, and as fixed and rotary wing pilot and instructor pilot, all in light business-type aircraft. Available October 1. Salary open. W-282-67

Agricultural Engineer for teaching or research in soil and water field with college or experiment station. Any location considered. Eastern U. S. preferred. Married. Age 38. No disability. B Applied Science (agricultural engineering) 1953, Canada. MSAE, 1954, University of California. Drainage research 2 years in Canada and 2 years in California. Design engineer with sprinkler installation company. War enlisted service 4 years as radar mechanic in Canadian Air Force. Available on reasonable notice. Salary open. W-283-68

Agricultural Engineer with 25 years experience in design and testing of corn pickers, combines, ensilage harvesters, power saws, manure spreaders, and last 5 years with land levelers, scrapers, and vegetable thinners. Age 51. Married. BSA, 1935, Ohio State University. Must stay in dry climate for wife's health. Available on short notice. Salary open. W-291-69

Agricultural Engineer for design, development, research, writing, or management in power and machinery with federal agency, manufacturer, consultant, or trade association. Any location. Prefer Midwest. Married. Age 37. No disability. BSAE, 1949, Iowa State University. Sales and service experience in father's farm equipment business part time while in school, and 3 years full time. Production piece work with drill manufacturer one year. Design and development work 11 years. War enlisted service in Air Force 2½ years as B-24 engineer. Available on reasonable notice. Salary open. W-294-70

Agricultural Engineer for development, research, extension, or sales in farm structures with industry or public service, preferably in Southeast. Any location considered. Military service commitments completed. Carpenter by trade. Married. Age 31. No disability. BSAE, 1960, University of Maine. Carpenter and military experience. Available on 15 days notice. Salary open. W-278-71

Agricultural Engineer for design, development, research, or sales in power and machinery with manufacturer, processor, or distributor. Any location. Married. Age 30. No disability. BSAE, 1951, Iowa State University. Progressive engineering experience and responsibility in farm equipment industry 9 years. Available on reasonable notice. Salary open. W-304-72

Agricultural Engineer for design, development, or research in power and machinery or soil and water field with industry or public service. Any location. Married. Age 43. No disability. BSAE, 1942, Virginia Polytechnic Institute. Farm background. Extension and research experience 3 years. Farm contracting 11 years. Special assignment 4 months with Spanish government as consultant on soil conservation machinery. War commissioned service in Corps of Engineers. Available January 1961. Salary $9,000. W 287-73

Agricultural Engineer for design, development, or research in farm structures or soil and water field with federal agency, manufacturer, consultant, or trade association in West. Married. Age 23. No disability. BSAE, 1959. Research assistant 3 years while in college. Junior design engineer on farm buildings one year. Available October 1. Salary $550 per month. W-297-74

Agricultural Engineer for design, development, research, or service in power and machinery, farm structures or soil and water with manufacturer. Any location in USA. Short time elsewhere. Willing to travel. Single. Age 23. No disability. BSAE, 1960, Rutgers University. Engineering trainee one summer; member of survey party one summer, SCS. Since graduation with building company in repair and correction work on project homes. Available on reasonable notice. Salary $5,000. W-300-75

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Agan, James R. — Territorial sales mgr., Portland Sales Branch, John Deere Co. (Mail) 1012 Princeton Ave., Wenatchee, Wash.

Bekki, Eiji — Farm adviser, agr. ext. office, Misawa dist., Aomori Prefectural Government, Misawa-Chikn-Nogyo-Kairyo-Fukyusho, 4 Chome, Honcho, Misawa City, Japan

Bianchi, William C.—Soil scientist (physics), (ARS) USDA. (Mail) 4882 E. Princeton Ave., Fresno 5, Calif.

DePauw, Richard A. — Product engr., eng. dept., East Moline Wks., International Harvester Co., East Moline, Ill.

Doles, Donald E. — Sales engr., Blue River Feed Mills. (Mail) 4120 N. Irvington, Indianapolis, Ind.

Gunn, Robert E.—Area engr., (SCS) USDA, P.O. Box 71, Meridian, Miss.

Janssen, Donald F. — Asst. plantation engr., Maui Pineapple Co., Ltd., Haliimaile, Maui, Hawaii

Ainsworth, Keith H. — Asst. gen. mgr. and superintendent of water, Coachella Valley County Water Dist., P.O. Box 1058, Coachella, Calif.

Andes, Bienvenido C.—Graduate student, agr. eng. dept., Oklahoma State University. (Mail) Box 51, Veteran's Village, Stillwater, Okla.

Jeoffrey, Muhammad M. A.—Asst. agr. engr. (res.), Agr. Eng. Workshop, Tandojam, West Pakistan

Jochetz, James E. — (With the U.S. Air Force). (Mail) R.R. 5, Box 444A, North Little Rock, Ark.

Karim, Bazlul — Deputy dir. of agr. and agr. engr., dept. of agr., Government of East Pakistan. (Mail) 39/D, Azimpura, Dacca, East Pakistan

Leonard, Clarence G. — Physicist, Southwestern Cotton Ginning Res. Laboratory, (ARS) USDA. (Mail) P.O. Box 332, Mesilla Park, N. M.

Liu, Hsin-Kuan — Assoc. prof. of irrigation and assoc. irrigation engr., irrigation dept., University of California, Davis, Calif.

Martin, John A. — Pres., John A. Martin & Co., P.O. Box 637, Sheboygan, Wis.

McCormick, William S., Jr. — Passenger, ind., farm tire and special products engr., The General Tire & Rubber Co., 1708 Englewood Ave., Akron, Ohio

Moorhead, Stanley T.—Student trainee, Lakeport Work Unit, (SCS) USDA. (Mail) P.O. Box 14, Kelseyville, Calif.

Myers, Theodore J. — Tire and special products engr., Ohio Rubber Co., Willoughby, Ohio

Roberts, John A. F. — Agr. engr., Tobacco Res. Board of Rhodesia and Nyasaland, P.O. Box 1909, Salisbury, Southern Rhodesia

Romero-Chavez, Jose J. — Graduate student, irrigation dept., University of California. (Mail) 313 J St., Davis, Calif.

Shai, Brin—Graduate student, agr. eng. dept., Technion Israel Institute of Technology. (Mail) 16 Hess St., Haifa, Israel

Snyder, Lee H. — Instructor, agr. eng. dept., Pennsylvania State University, University Park, Pa.

Thomas, Edward T. — Real estate mgr., Warrick Wks., Aluminum Co. of America, Newburgh, Ind.

Wickham, John L. — Jr. product engr., Papec Machine Co., Shortsville, N. Y.

Wilson, James N. — Asst. field engr., Texaco Exploration Co. (Mail) Okla, Sask., Canada

TRANSFER OF MEMBERSHIP

Andersson, Erik Y. — Sr. res. agr. engr., Swedish Institute of Agr. Eng., Ultuna, Uppsala 7, Sweden (Affiliate to Member)

Griffin, Jack G. — Assoc. prof. and assoc. agr. engr., agr. exp. sta., Mississippi State University. (Mail) Box 834, State College, Miss. (Associate Member to Member)

Porterfield, Jay G. — Prof. of agr. eng., agr. eng. dept., Oklahoma State University, Stillwater, Okla. (Associate Member to Member)

Sisson, Donald R. — Ext. agr. engr., Purdue University, Agr. Eng. Bldg., Lafayette, Ind. (Associate Member to Member)

Vaughan, Lee E. — Sr. proj. engr., New Idea Div., Avco Corp. (Mail) R.R. 1, Coldwater, Ohio (Associate Member to Member)

STUDENT MEMBER TRANSFERS

Arnn, Edgar G. — (University of Arkansas) Winnebago Rural Electric Coop. Assn., Thompson, Iowa

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